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A PLEISTOCENE DIATOM ASSEMBLAGE FROM ELLESMERE ISLAND, NORTHWEST TERRITORIES

SIGRID LICHTI-FEDEROVICH

Canada

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A PLEISTOCENE DIATOM ASSEMBLAGE FROM CAPE STORM, ELLESMERE ISLAND, NORTHWEST TERRITORIES

Abstract

Diatom analysis of a Pleistocene sediment sample from Cape Storm, Ellesmere Island, dated at 35 000 to 43 000 radiocarbon years, resulted in the identification and ecological characterization of 136 taxa. The diatom thanatocoenosis represents a littoral constituent marked by the preponderance of benthic and epontic species and a neritic component manifested by meroplanktonic forms with cryophilic diatoms and stenothermal taxa. Floristic analysis indicates that deposition occurred in a shallow coastal marine environment having lowered salinities and cold water conditions influenced by ice.

Résumé

L'analyse des diatomées d'un échantillon, vieux de 35 000 à 43 000 ans, de sédiment pléistocène provenant du cap Storm dans l'île Ellesmere, a mené à l'identification et à la description écologique de 136 taxons. La biocénose des diatomées présente un élément littoral caractérisé par une prépondérance d'espèces benthiques et épontiques et une composante néritique qui se distingue par la présence de formes méroplanctoniques à diatomées crypohiles et à taxons sténothermiques. L'analyse floristique indique que la mise en place a eu lieu dans un milieu côtier peu profond et à faible degré de salinité, dont les eaux froides subissaient l'effet des glaces.

INTRODUCTION

This report represents an application of diatom analysis as a paleoecological tool to the study of the Pleistocene of the Canadian Arctic. Diatom analytical techniques assist in the confirmation of geomorphologically determined Pleistocene events and in the reconstruction of environmental conditions that prevailed during the time of deposition. Abundance and diversity of the biogenic component of the sample material provided additional stimulus for this investigation.

The diatom-bearing material was collected by W. Blake, Jr. and R.J. Richardson, from a 20 cm-thick sandy silt horizon a few metres below the top of a massive sand unit which occurs along the river bisecting Andersrag Beach (Fig. 1). This deposit (GSC loc. 96377; 76°24'N, 87°34'W) is located approximately 6.5 km north of Cape Storm, southern Ellesmere Island, Northwest Territories (Fig. 2; Blake, 1975, 1976). Radiocarbon age determinations of **Mya truncata** shells and marine algae recovered from the sample level (63 m a.s.l.) have given finite ages in the range of 35 000 to 43 000 radiocarbon years (Blake, 1980). The massive sand unit is overlain by a 1 to 2 m-thick unit of coarse detritus (cobbles, boulders, and sand) and by a surface veneer of Holocene beach shingle.

Acknowledgments

With sincere appreciation and gratitude I acknowledge my indebtedness to the following: W. Blake, Jr. for his kindness in providing sample material, pertinent stratigraphic information, and location photograph; D.W. Walker, for his technical skill in the preparation of SE micrographs; U. Miller, Geological Survey of Sweden, Uppsala and University of Stockholm, and R.A. Horner, Department of Oceanography, University of Washington, Seattle, for their helpful comments and review of the manuscript; G. Hasle and E.E. Syvertsen, University of Oslo, for their valuable assistance with critical identification of **Thalassiosira** and **Melosira** species, and S.I.C. Hsiao, Department of Fisheries and Oceans, Sainte-Anne-de-Bellevue, Quebec, for his examination of light micrographs and revision of synonymy.

MATERIALS AND METHODS

Samples were collected over a 5 m-long segment of the sandy silt-rich horizon at Cape Storm and then were pooled. Cursory examination of the sample material revealed an abundance of foraminifera, ostracoda, and echinoid spines. Some of these faunal macro-constituents were picked out by hand using a binocular microscope before sample treatment for diatom analysis. Other samples were collected near the base of the massive sand unit, but no diatoms were found.

Preparation of 12 aliquots of the fossiliferous composite for diatom identification followed the method by Van der Werff (1955): A 1 cm^3 sediment sample was placed in a 1500 mL beaker and was covered with 30 per cent H_2O_2. A small amount (tip of spatula) of $K_2Cr_2O_7$ was added to the mixture. After several minutes a violent reaction occurred which quickly subsided. This digestion was followed by decantations with distilled water every 24 hours. Strewn slides for microscopical examination were prepared the conventional way, using Hyrax as mounting medium.

For critical evaluation of structural detail a Leitz Ortholux x90 oil immersion objective was used. Light micrographs (Plates 1-18) were taken with oil immersion, the Wild Photoautomat MPS 50, and Panatomic X-35 mm film. Preparation for scanning electron microscopy followed the procedure described by Lichti-Federovich (1979). All electron micrographs (Plates 19-22) were obtained with the ETEC Autoscan at 20 kV.

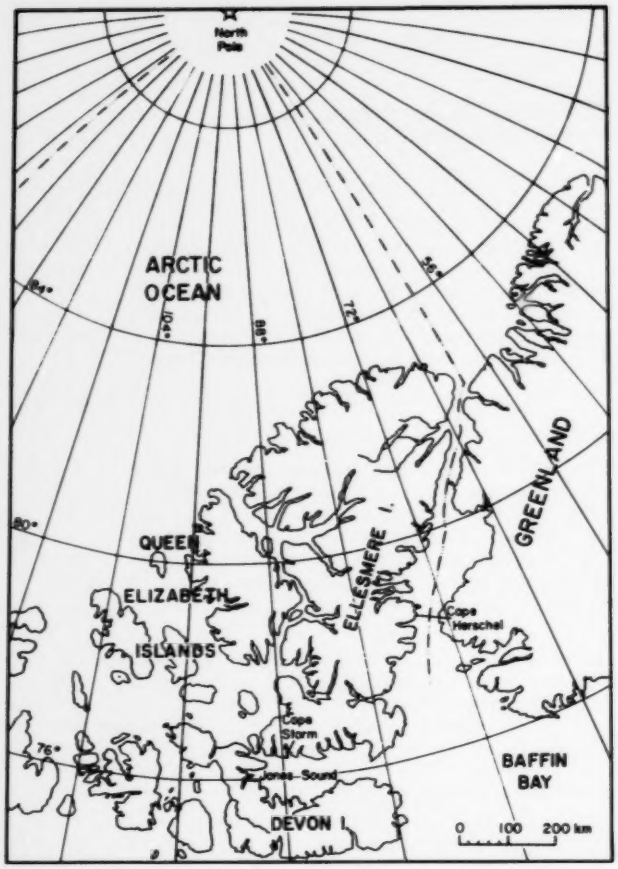

Figure 1. *Location map indicating sampling site, Cape Storm, southern Ellesmere Island.*

SYSTEMATICS AND AUTECOLOGY

Diatom analysis of the Pleistocene sediment from Cape Storm yielded 136 taxa, which are illustrated in Plates 1 to 22.

Diatoms were identified to species whenever possible; however, several entities could be assigned to genus only. Since morphological description and systematic classification of new forms are beyond the scope of this report, no attempt has been made to do so, with one exception – **Navicula subfossilis** sp. nov. (Lichti-Federovich, 1980), which occurred in large numbers. All other undefined taxa have been grouped under their generic designation. Critical identification and taxonomic classifications were supported by the following monographs: Cleve and Grunow (1880), Heiden and Kolbe (1928), Hustedt (1930, 1959a, 1971), Cleve-Euler (1951, 1952, 1953, 1955), Hendey (1964), and Peragallo (1897-1908). Additional references include: Riznyk (1973), Foged (1973, 1975), McIntire and Reimer (1974), and Cox (1975). Taxonomic delineation of some centric taxa was greatly aided by Hasle and Heimdal (1968), Heimdal (1971, 1973, 1974), Hasle (1974), and Syvertsen (1979).

Relative frequency determinations were based upon examination of 67 slides. These ratings are: **d** = dominant; **sd** = subdominant; **s** = subordinate; and **o-r** = occasional or rare.

The diatom taxa are presented in alphabetical order in Tables 1 to 3 accompanied by ecological and distributional information. This tabular summary provides a frame of reference which facilitates the characterization of the diatom flora and permits a more concise conceptual basis for the interpretation of environmental conditions. Because of the large number of sources for ecological and distributional data, only those references providing the largest amount of information are listed.

Salinity tolerance of the various diatom taxa as recorded in Table 1 is based on specific halinity determinations by Simonsen (1962) with supplementary information by Edsbagge (1968). The general salinity grouping represents a composite utilizing halinity ratings by Kolbe (1927), Hustedt (1939-40, 1957, 1959b), Van der Werff (1960), and many others.

Table 2 indicates the mode of living and substrate relationship; the main references are Brockmann (1950), Dahm (1956), Crosby and Wood (1959), Hendey (1964), Rao and Lewin (1976), and Ramm (1977).

Information for Table 3 depicting climatic/geographic affinity has been abstracted from Ostenfeld (1903, 1910), Hustedt (1955), Brunel (1970), Simonsen (1974), Ricard (1976), McIntire and Moore (1977), and Hasle (1977). Distributional data with special reference to Ellesmere Island were obtained from Dickie (1880), Cleve (1883, 1884), and Seidenfaden (1947). General arctic distribution was compiled mainly from Cleve (1873, 1883, 1896), Dickie (1877), Østrup (1895, 1897, 1910), Gran (1904b), Mann (1925), Grøntved and Seidenfaden (1938), and Seidenfaden (1947). Summarization of ice associated occurrence in arctic regions was supported by Cleve (1898), Gran (1899, 1904a, b), Van Heurck (1909), Østrup (1910), Ostenfeld (1910), Mann (1925), Meister (1930), Usachev (1946, 1949), Fukushima (1965), Meguro et al. (1966, 1967), Grant and Horner (1976), Saito and Taniguchi (1978), and Hsiao (1980). Tabulation of ice associated distribution in the Antarctic incorporates the following references: Heiden and Kolbe (1928), Burkholder and Mandelli (1965), Krebs (1977), Lipps et al. (1977), and Van Heurck (1909) whose compilation of the distribution and ice association of polar diatoms merits special mention for it includes references to 27 authors spanning the years 1883 to 1906.

THE DIATOM FLORA

General Considerations

Floristic assessment of any fossil assemblage and subsequent translation of its ecological parameters into a valid paleoenvironmental framework is subject to certain limitations. Restrictions imposed by preservational and sedimentological factors especially affect the evaluation and interpretation of diatom thanatocoenoses of high energy biotopes such as nearshore shelf environments or coastal areas where turbulence, currents, and wave action cause mixing, fragmentation, and redeposition. In polar regions heavy fragmentation due to grounded ice may also prevent an accurate representation of the fossil biotope. Bursa (1963), confirming the observations of other investigators, cited the abrasive and mixing effect of ice on surface sediment along the Alaskan coast. Likewise, Carey and Ruff (1977), stating various references, emphasized the effect of ice scouring on the inner and middle Beaufort continental shelf region where it causes phytobenthic faunal destruction resulting in patchiness and reduction of standing stock. Additional changes in the floristic composition of fossil diatom associations are caused by differential diagenetic dissolution predominantly affecting the more weakly silicified species. For example, Krebs (1977) determined a cumulative biocoenotic preservation rate of only 68% in the

Figure 2. *Aerial view of Andersrag beach, north of Cape Smith Ellesmere Island. The arrow indicates the sampling site.*

corresponding thanatocoenosis of nearshore and basin sediments at Arthur Harbour, Antarctica, with major losses due to grazing and dissolution, primarily affecting the following genera: **Achnanthes, Chaetoceros, Dactyliosolen, Nitzschia, Synedra,** and **Tropidoneis.**

The diatom component of the Pleistocene fossiliferous sand sample from Cape Storm exhibits some fragmentation and a more marked incidence of dissolution. Whereas the fragmented fraction shows the same floristic composition as the well preserved fraction, dissolution appears to have selectively affected the frustules of many small, lightly silicified diatoms such as species of **Fragilaria, Amphipleura, Licmophora,** and other small naviculoid forms.

Furthermore, the Cape Storm thanatocoenosis may not only incorporate spatial fluctuations but also temporal changes representing seasonal successions which characterize arctic environments, resulting in an admixture of ice diatoms and spring or summer plankton forms.

Aside from preservational limitations inherent in the assessment of any fossil assemblage, taxonomic evaluation of the Pleistocene diatom flora of Cape Storm is hindered by uncertainties arising from the number of undeterminable forms that elude precise autecological delineation. These systematic and ecologic ambiguities are largely reflections of the distinct lack of taxonomic and distributional studies and can be directly ascribed to the dearth of information on the marine littoral vegetation of arctic coastal areas. In this regard, I acknowledge and give credit to the excellent treatise by Korotkevich (1960) on the diatom flora of the Barents Sea littoral zone. Unfortunately his account does not include many ice associated taxa. Although these restrictions may limit or preclude a detailed paleoenvironmental reconstruction, they do not greatly influence an assessment of the general character of the diatom flora and its paleoecological interpretation.

Composition and Characteristics

The Pleistocene diatom complex studied here, on the basis of floristic composition (Tables 1, 2, 3), can be divided into a marine littoral and a neritic constituent. The littoral element largely comprises benthic and epontic species of cosmopolitan distribution (Tables 2, 3) and is characterized by the abundant representation of the genus **Amphora.** The marked eurythermal nature of many non-planktonic species found in temperate as well as cold waters has been attested to by Castenholz (1967) comparing marine littoral assemblages from the Oregon, Norwegian, and British coasts. Included in the cosmopolitan element of the diatom complex are also taxa designated by early investigators as arctic or arcto-boreal whose broad ecological amplitude and cosmopolitan distribution have since been firmly established, a trend likely to continue with extended investigations of marine littoral biocoenoses. The taxon **Achnanthes groenlandica,** for example, which previously had been assigned arctic affinity, with the discovery of additional finds in Africa, Europe, and the Galapagos Islands, has now been reclassified as cosmopolitan (McIntire and Moore, 1977).

Table 1

Salinity tolerances of the diatoms from a Pleistocene deposit near Cape Storm, Ellesmere Island

		General halinity rating						Tidal tolerance		Polyhalobous*					
		Marine	Marine brackish	Brackish	Brackish fresh	Fresh	Euryhaline	Ampotixen	Indifferent	Oligo euryhaline	Melo euryhaline	Meso euryhaline	Pleio euryhaline	Mesohalobous	Oligohalobous
	CENTRICAE														
	ACTINOCYCLUS Ehrenberg														
o-r	**Actinocyclus** spp.														
	BACTEROSIRA Gran														
sd	**Bacterosira fragilis** (Gran) Gran	x					x								
	BIDDULPHIA Gray														
sd	**B. aurita** (Lyngb.) Bréb. et God.	x	x	x			x		x		x				
s	**B. aurita** var. **obtusa** (Kütz.) Hust.	x							x						
	COSCINODISCUS Ehrenberg														
o-r	**Coscinodiscus centralis** Ehr. (fragm.)	x													
o-r	**C. curvatulus** var. **lariana** Cleve & Grun.	x													
o-r	**C. curvatulus** var. **minor** (Ehr.) Grun.	x													
o-r	**C. divisius** Grun.	x													
o-r	**C. kützingii** A.S.	x													
o-r	**C. lacustris** var. **hyperborea** (Grun.) Rattr.		x	x	x		x				x				
o-r	**C. lacustris** var. **septentrionalis** Grun.														x x
	DETONULA Gran														
	D. confervacea (Cleve) Gran	x	x												
	HYALODISCUS Ehrenberg														
o-r	**H. laevis** Ehr.	x													
o-r	**H. scoticus** (Kütz.) Grun.	x	x	x			x		x			x		x	
o-r	**H. subtilis** Bail.	x									x				
	MELOSIRA Agardh														
s	**M. arctica** (Ehr.) Dickie	x													
s	**M. moniliformis** (O. Müller) Ag.	x	x	x			x						x		
s	**M. nummuloides** (Dillw.) Ag.	x	x	x			x		x			x			
	Melosira sp.														
	PODOSIRA Ehrenberg														
s	**P. hormoides** var. **arctica** (Cleve ex Cleve et Grun.) Hust.	x							x						
	Podosira sp.														
	POROSIRA Jörgensen														
s	**P. glacialis** (Grun.) Jörg.	x													
	RHIZOSOLENIA Ehrenberg														
o-r	**R. hebetata** fo. **semispina** (Hens.) Gran	x													
	SKELETONEMA Greville														
o-r	**S. costatum** (Grev.) Cleve	x	x				x						x		
	STEPHANODISCUS Ehrenberg														
o-r	**S. astraea** (Ehr.) Grun. in Cleve et Grun.			x	x	x	x				x				
	THALASSIOSIRA Cleve														
sd	**T. antarctica** Comb.	x													
sd	**T. constricta** Gaarder	x													
o-r	**T. eccentrica** (Greg.) Hasle	x	x												
s	**T. hyalina** (Grun. in Cleve et Grun.) Gran	x													
o-r	**T. hyperphila** (Grun.) Jörg.	x													
o-r	**T. nordenskiöldii** Cleve	x													
	Thalassiosira spp.										x				

		General halinity rating						Tidal tolerance		Polyhalobous*					
		Marine	Marine brackish	Brackish	Brackish fresh	Fresh	Euryhaline	Ampotixen	Indifferent	Oligo euryhaline	Melo euryhaline	Meso euryhaline	Pleio euryhaline	Mesohalobous	Oligohalobous
	CERATONEIS Ehrenberg														
o-r	**C. arcus** (Ehr.) Kütz. var. **linearis** Holmb. (fragm.)					x									x
	COCCONEIS Ehrenberg														
s	**C. costata** Greg.	x							x		x				
s	**C. scutellum** Ehr.	x	x	x			x		x				x		
s	**C. scutellum** var. **stauroneiformis** W. Sm.	x							x			x			
	Cocconeis spp.														
	CYMBELLA Agardh														
o-r	**C. angustata** (W. Sm.) Cleve					x									x
	DIPLONEIS Ehrenberg														
s	**D. bomboides** var. **media** (Grun. in Cleve et Grun.) Hust.	x						x			x				
o-r	**D. interrupta** (Kütz.) Cleve var.	x	x	x			x	x						x	
s	**D. smithii** (Bréb. in W. Sm.) Cleve	x	x	x			x		x				x		
s	**D. subcincta** (A.S.) Cleve	x						x			x				
	FRAGILARIA Lyngbye														
o-r	**F. pinnata** Ehr.			x	x	x	x								x
o-r	**F. striatula** Lyngb.	x													
	Fragilaria spp.														
	GOMPHONEMA Agardh														
o-r	**G. geminatum** var. **sibirica** Grun.					x									x
o-r	**G. kamtchaticum** Grun.	x								x					
o-r	**G. pseudoexiguum** Simonsen			x			x							x	
	GRAMMATOPHORA Ehrenberg														
o-r	**G. angulosa** Ehr.	x						x	x		x				
o-r	**G. arctica** Cleve	x													
	GYROSIGMA Hassall														
o-r	**G. arcticum** (Cleve) Cleve	x													
	LICMOPHORA Agardh														
o-r	**L. gracilis** var. **anglica** (Kütz.) Perag.	x					x		x			x			
	Licmophora spp.														
	NAVICULA Bory														
s	**N. cancellata** Donk.	x					x		x			x			
s	**N. cancellata** var. **apiculata** (Greg.) Perag.	x							x						
s	**N. cancellata** var. **subapiculata** Grun.	x							x						
o-r	**N. comoides** (Dillw.) Perag.	x									x				
s	**N. compressicauda** A.S.	x													
o-r	**N. cluthensis** Greg.	x													
o-r	**N. cluthensis** var. **striolata** Grun.	x													
s	**N. digitoradiata** (Greg.) in Pritch.	x	x	x			x		x					x	
s	**N. directa** (W. Sm.) Ralfs in Pritch.	x	x					x			x	x			
s	**N. directa** var. **remota** Grun.	x						x							
s	**N. directa** var. **subtilis** (Greg.) Cleve	x						x							
o-r	**N. dissipata** Hust.												x		
s	**N. distans** (W. Sm.) Ralfs in Pritch.	x													
o-r	**N. finmarchica** (Cl. & Grun.) Cleve	x					x		x		x				
o-r	**N. forcipata** Grev.	x					x		x			x			
o-r	**N. gelida** Grun.	x													
sd	**N. grevillei** (Ag.?) Heib.	x				x	x?			x					

	PENNATAE													
	ACHNANTHES Bory													
o-r	**A. arctica** var. **baltica** Grun.	x												
s	**A. brevipes** Agardh	x	x	x			x		x			x		x
o-r	**A. brevipes** var. **minor** Perag.	x	x											
s	**A. delicatula** (Kütz.) Grun. in Cleve et Grun.	x	x	x			x		x					x
s	**A. groenlandica** (Cleve) Grun. in Cleve et Grun.	x												
o-r	**A. hauckiana** Grun.	x	x	x	x		x		x					x
o-r	**A. polaris** Østr.	x												
	Achnanthes spp.													
	AMPHIPLEURA Kützing													
s	**A. rutilans** (Trent. ex Roth) Cleve	x	x	x			x		x					x
	AMPHIPRORA Ehrenberg													
o-r	**A. gigantea** var. **septentrionalis** (Grun.) Cleve	x						x?		x				
	AMPHORA Ehrenberg													
o-r	**A. acutiuscula** Kütz.	x	x	x										
s	**A. angusta** Greg.	x	x						x			x		
s	**A. angusta** var. **arctica** Cleve	x	x						x					
s	**A. angusta** var. **oblongella** (Grun.) Cleve	x	x						x					
o-r	**A. angustissima** Heid. & Kolb.	x	x											
s	**A. catarinaria** Choln.													
s	**A. crassa** Greg.	x						x		x				
s	**A. cymbifera** Greg.	x							x	x				
s	**A. graeffeana** Hend.	x							x	x				
s	**A. holsatica** Hust.			x										
o-r	**A. interrupta** (non Pant.) Heid. & Kolb.													
s	**A. laevis** var. **laevissima** (Greg.) Cleve	x	x						x	x				
s	**A. libyca** var. **baltica** (Brander) Cleve-Euler			x										
o-?	**A. lindbergii** Cleve-Euler	x												
o-r	**A. lineolata** Ehr.		x	x			x		x					x
o-r	**A. lineolata** var. **pticata** (Greg.) A. Cleve													
o-r	**A. macilenta** Greg.	x									x			
o-r	**A. novae caledoniae** Grun.	x												
s	**A. oblonga** Greg.	x							x					
o-r	**A. ocellata** Donk.	x							x	x				
o-r	**A. ostrearia** var. **vitrea** (Cleve) Cleve	x					x		x	x				
s	**A. ovalis** var. **libyca** (Ehr.) Cleve			x	x		x		x					x
s	**A. proteus** Greg.	x	x				x		x			x		
s	**A. proteus** var. **oculata** Perag.	x												
o-r	**A. scabriuscula** Cleve & Grove													
o-r	**A. wisei** (Sal.) Sim.								x	x				
o-r	**A. weissflogii** A.S. in Schmidt et al.													
	Amphora spp.													
	CALONEIS Cleve													
o-r	**C. brevis** (Greg.) Cleve	x	x	x			x		x		x			
s	**C. liber** (W. Smith) Cleve	x						x	x	x				
o-r	**C. liber** var. **elongata** Grun.	x												
	Caloneis sp.													
	CAMPYLODISCUS Ehrenberg													
o-r	**C. angularis** Greg.	x												

o-r	**N. litoricola** Hust.								x		x			
o-r	**N. lyra** var. **atlantica** A.S.	x							x		x			
o-r	**N. palpebralis** var. **semiplena** (Greg.) Cleve	x								x				
o-r	**N. pennata** A.S.													
o-r	**N. reichardtii** var. **tschuktschorum** Cleve	x												
s	**N. rostellata** Kütz.	x	x	x			x							
d	**N. subfossilis** n. sp.													
o-r	**N. subinflata** Grun.	x	x	x			x							
o-r	**N. superba** Cleve	x												
o-r	**N. transitans** Cleve	x												
	Navicula spp.													
	NITZSCHIA Hassall													
o-r	**N. angularis** W. Sm.	x						x?		x	x			
o-r	**N. cylindrus** (Grun.) Hasle	x												
s	**N. grunowii** Hasle	x												
o-r	**N. hybrida** Grun.													
o-r	**N. marginulata** Grun. var. **minuta**													
o-r	**N. praelonga** Cleve													
o-r	**N. recta** Hantzsch ex Rabh.													
o-r	**N. sigma** (Kütz.) W. Sm.	x	x	x			x		x				x	
s	**N. socialis** Greg.													
s	**N. socialis** var. **baltica** Grun.													
	Nitzschia spp.													
	PINNULARIA Ehrenberg													
o-r	**P. ambigua** Cleve	x					x		x		x	x		
o-r	**P. quadratarea** (A.S.) Cleve	x							x			x		
o-r	**P. quadratarea** var. **constricta** (Østr.) Heid.	x												
	PLEUROSIGMA W. Smith													
o-r	**P. longum** Cleve	x												
o-r	**P. strigosum** W. Sm.	x	x	x										
	SURIRELLA Turpin													
o-r	**Surirella** sp. (fragment)													
	SYNEDRA Ehrenberg													
s	**S. camtschatica** Grun.	x												
s	**S. camtschatica** var. **finnmarchica** Cleve et Grun.	x												
s	**S. tabulata** (Ag.) Kütz.	x	x	x			x		x				x	
	Synedra spp.													
	TABELLARIA Ehrenberg													
o-r	**T. fenestrata** (Lyngb.) Kütz.					x								x
	THALASSIONEMA Grunow													
o-r	**T. nitzschioides** (Grun.) V.H.	x					x							
	THALASSIOTHRIX Cleve & Grunow													
o-r	**Thalassiothrix** sp.													
	TRACHYNEIS Cleve													
s	**T. aspera** (Ehr.) Cleve	x						x	x		x			
s	**T. aspera** var. **media** (Grun.) Cleve	x												
	TROPIDONEIS Cleve													
o-r	**Tropidoneis** sp.													
	MISC.													
	DISTEPHANUS Stöhr													
o-r	**D. octonarius** (Ehr.) Defl. var. **octonarius**	x												

*Halinity rating according to Simonsen (1962):

Polyhalobous oligo-euryhaline = 35 to ≥ 30 ‰
Polyhalobous meio-euryhaline = 35 to ≥ 20-17 ‰
Polyhalobous meso-euryhaline = 35 to ≥ 8-10 ‰
Polyhalobous pleio-euryhaline = 35 to ≥ 3-5 ‰

Whereas the littoral component is largely composed of eurythermal taxa, the neritic constituent, conversely, is represented almost exclusively by meroplanktonic species of restricted geographic/climatic affinity; its principal element, the bipolar **Thalassiosira antarctica**, displays strong stenothermal and stenohaline characteristics. Other predominantly arctic species characterizing the neritic realm include: **Thalassiosira constricta, Thalassiosira hyalina, Melosira arctica, Bacterosira fragilis, Detonula confervacea,** and **Porosira glacialis.**

Somewhat surprising, however, in view of its general distribution in all arctic and subarctic waters as well as its recorded mass occurrence from Baffin Bay and Davis Strait (Cleve, 1896), is the meagre representation of **Thalassiosira nordenskiöldii** – a cold water, meroplanktonic species – encountered only once in the Cape Storm assemblage. Whether this near absence of **Th. nordenskiöldii** is indicative of a more pronounced polar influence cannot be stated with certainty.

Rhizosolenia hebetata fo. **semispina** also merits special mention. Its occurrence in the pelagic element dominated by arctic and arcto-boreal taxa gives support to Smayda's (1958) assumption that **Rh. hebetata** fo. **semispina** is indigenous to arctic regions. This find also accords well with the distributional characterization of **Rh. hebetata** fo. **semispina** by Paasche (in Guillard and Kilham, 1977) as a distinct component of the arctic or polar vegetation area of the Norwegian Sea.

Aside from the littoral association with epiphytic nature of predominantly cosmopolitan forms and a decidedly arctic element containing mostly meroplanktonic species, this fossil admixture also includes several subordinate floristic elements. In addition to ice diatoms and a small oligohalobous component comprising an insignificant number of freshwater forms (Table 1), heterogeneity is further indicated by a minor holoplanktonic constituent of allochthonous origin.

This Pleistocene assemblage may also contain a small number of relict species. It cannot however, be resolved with certainty if some of the undeterminable forms represent extant species or if the diatoms are of more recent origin which until now have eluded detection (e.g. Plate 5, fig. 34).

The isolated occurrences of morphological anomalies such as the teratologic form (Plate 6, fig. 10) is likely to indicate stress conditions in shallow marine environments, perhaps induced by salinity changes.

In general, the Cape Storm diatom flora can be characterized as marine littoral to neritic with subordinate brackish and minor freshwater constituents.

Floristic Comparisons

The Pleistocene diatom flora of Cape Storm lacks a modern and/or fossil analogue, a fact less surprising if one considers that the study of arctic phytocoenoses, aside from incidental collections, has been largely restricted to comparative phytoplankton investigations. Furthermore, contrary to oceanic phytocoenoses which express a more pronounced spatial uniformity, floristic composition of littoral phytocoenoses exhibits greater qualitative fluctuations caused by variations in salinity, substrate, and other hydrographic factors, allowing only a correlative approximation even between samples from a spatially limited area.

Collections of modern samples from estuarine and lagoonal environments near Cape Storm failed to provide positive floristic correlation due to their relatively high oligohalobous content. Some taxonomic similarity was noted to the diatom association of material collected near Rosse Bay, Cape Herschel, Ellesmere Island, from upturned sea ice which contained incorporated bottom sediment; the modern assemblage, however, showed lack of diversification and a notable absence of **Biddulphia aurita.**

It was the distinct prominence of such cryophilic species as **Navicula algida, N. trigonocephala, N. detersa, N. derasa, N. obtusa,** and **N. transitans** in a diatom assemblage recovered from a surficial seawater sample obtained from a crack in sea ice about 200 m offshore at Rosse Bay, southern Ellesmere Island, that precluded a more than slight similarity to the Cape Storm fossil assemblage.

This distinct lack of some of these cryophilic taxa in the Cape Storm fossil complex also prohibits little more than partial correlation to a recent enumeration of sea ice associated diatoms from Eclipse Sound, northern Baffin Island (Hsiao, 1980). Nevertheless, both species lists contained **Navicula cluthensis,** a marine littoral form known from Litorina sediments and from the western Baltic (Cleve-Euler, 1953; Simonsen, 1962), which to my knowledge has not been reported previously from arctic regions.

Although the Pleistocene diatom flora as a whole defies positive floristic correlation, some of its elements display compositional similarity to modern equivalents. The neritic component, for example, shows close resemblance to a phytoplankton collection recorded by Seidenfaden (1947) from the mouth of Jones Sound, off Ellesmere Island, comprising the following species: **Bacterosira fragilis, Melosira arctica, Porosira glacialis, Rhizosolenia hebetata** fo. **semispina, Thalassiosira bioculata, Thalassiosira nordenskiöldii, Thalassiosira antarctica** and **Nitzchia grunowii.**

Close floristic similarity exists between the littoral constituent and the diatom content of bottom samples recovered from the Kara Sea (Cleve and Grunow, 1880) and to the diatom association of the Murman coast (Korotkevich, 1960). Some variance expressed by the abundant representation of the genus **Amphora** in the Cape Storm assemblage and by the subordinate position of its oligohalobous forms as compared to the Barents Sea littoral association seems likely the result of hydrographic differences.

Favourable comparisons of littoral elements, even between geographically widely separated regions, are attributable no doubt to the broad ecological amplitude exhibited by the majority of benthic and epontic species. In this context it may be mentioned that Castenholz (1963), intrigued by the 80 per cent synchrony of littoral diatoms found on both the British and Oregon coasts, raised the question of continuous distribution of cosmopolitan littoral and sublittoral diatoms over arctic shores. Such distributional continuity does in fact exist.

A search for corresponding fossil equivalents afforded some analogy with the diatom floras of various Quaternary marine deposits from arctic Russia, the semblance being supported mainly by the psychrophilic neritic elements.

In the context of compositional assessment and floristic comparisons, it is pertinent to mention that misidentification of **Thalassiosira antarctica** resting spores may have occurred in early arctic marine phytoplankton records and diatom enumerations of marine littoral and sea ice associated biotopes prior to the emended description by Hasle and Heimdal (1968). In his study of resting spore formation, Syvertsen (1979) refers to previous misnomers of **Th. antarctica** semi-endogenous resting spores as **Thalassiosira fallax** and of its endogenous resting spores as belonging to **Thalassiosira gravida.** Although both species can be classified as marine, neritic, meroplanktonic, and arcto-boreal, autecological characterization of **Thalassiosira antarctica** discloses a more strongly stenothermal nature (calculated mean T-0.05°C) which is expressed by its polar

distribution compared to the more boreal affinity shown by **Thalassiosira gravida** (T opt. 4.2°C). Such taxonomic confusion would certainly affect concise delineation of environmental interpretations formulated before the event of systematic clarification, even if the ecological and distributional differences appear only slight.

DISCUSSION

Evaluation and assessment of the depositional environment as reflected by the fossil diatom flora is based on a qualitative comparison to recent species with regard to selected ecological parameters. Many members of the phytobenthos, however, exhibit a wide ecological amplitude and broad latitudinal range; they occur in coastal, lagoonal, and estuarine habitats and display a cosmopolitan distribution. Furthermore, assessment of the associational structure of the diatom complex is somewhat limited by preservational factors and taxonomic uncertainties. Biotope reconstruction therefore, rests mainly on autecological characterization of the numerically dominant taxa that exhibit narrow ecological and distributional ranges.

It is the absolute dominance of the pennate diatom **Navicula subfossilis** sp. nov. that affirms its autochthony and warrants its use as indicator species. Unfortunately, however, its autecological requirements are not known. Nevertheless, its obvious structural resemblance and apparent geographic/climatic affinity to the closely related **Navicula subinflata** predicates similarity in ecological amplitude. According to Hustedt (1971) the areas of distribution for **Navicula subinflata** are Greenland and the Siberian coast, Wankarema, the western Baltic, North Atlantic coasts, and Arctic seas. Usachev (1949) reported its occurrence from the upper surface of ice.

Paleoclimate

Paleoclimate reconstruction is based principally on the thermal requirements of members of the neritic constituent, because the eurythermy of most littoral species and the unknown distributional range of **Navicula subfossilis** preclude their use as paleoclimatic indicators. The prevalence of the bipolar **Thalassiosira antarctica** – a stenothermal species with an observed T range from -1.77° to 3.49°C in Antarctic waters (Smayda, 1958) – clearly indicates the pronounced arctic nature of the neritic constituent. Bipolarity as indicator of restricted latitudinal affinity is also expressed by **Porosira glacialis** (optimal temperature +1.6°C; Brunel, 1970). Arctic affinity and cold water regime are further evidenced by the presence of the arctic endemics **Bacterosira fragilis** (mean T +1.4°C; Smayda, 1958) and **Thalassiosira kryophila**, the stenotherm **Detonula confervacea** (optimal temperature -0.1°C according to Ostenfeld (1913), 0.1°C according to Cleve-Euler (1951); Brunel, 1970), the cold water species **Thalassiosira constricta**, **Thalassiosira hyalina** (mean temperature 2.3°C; Smayda, 1958), and the circumpolar **Melosira arctica**.

Other floristic elements of particular paleoclimatic significance denoting strong arctic affinity are cryoplanktonic species such as **Nitzchia grunowii**, **Melosira arctica**, **Navicula distans**, **Navicula directa**, **Thalassiosira antarctica**, and **Nitzchia cylindrus**. The latter represents a bipolar cold water form which has been described as dominant species in surface type plankton ice (Fukushima and Meguro, 1966).

Although the Cape Storm diatoms provide no certain indication of proximity or extent of sea ice cover, arctic marine biotopes are intimately connected with and strongly influenced by the presence of ice. While there is a noted absence or underrepresentation of certain cryophilic taxa as evidenced in Table 3, most of the diatoms listed have been found closely associated with ice – shelf ice, pack ice, fast ice, drift ice, ice floes, ice lumps, under ice, in ice, on ice, and in channels between ice. In addition, aside from the distributional characterization of the dominant meroplanktonic taxon **Thalassiosira antarctica** as indicator of either coastal or ice border proximity (Hasle and Heimdal, 1968), it is the marked representation of this species in the form of resting spores that suggests prevailing sea ice or its close proximity. For example, Smayda (1957) refers to the common occurrence of resting spores embedded in arctic ice. Furthermore, the high frequency of cosmopolitan benthic and epiphytic diatoms in the Cape Storm assemblage does not preclude or weaken an inferred ice-dominated environment. Bunt and Wood (1963) stated: "The epontic community in sea-ice habitat consists as it does in the estuaries of lower latitudes of attached species: **Pleurosigma**, **Nitzschia**, **Amphiprora**, **Fragilaria** and non-attached species living with them as part of the community (**Biddulphia**, **Coscinodiscus**, **Asteromphalus**)"; this statement is supported by a photograph illustrating the abundant occurrence of epiphytic diatoms under sea ice (Edsbagge, 1968). Thus, however tentative, the collective impression strongly suggests a depositional environment influenced by the proximity of sea ice.

Paleosalinity

Paleosalinity, a significant means of establishing marine depositional environments, is inferred from general halinity groupings abstracted from various reference sources and from a more refined scheme conceived by Simonsen (1962). Simonsen's halinity ratings, however, have only provisional value since they have been applied to only one environment, namely the western Baltic whose high Ca content may have resulted in tolerance amplification.

The marked floristic heterogeneity of the Cape Storm fossil diatom complex, which characterizes most marginal marine environments, is notably reflected in salinity preference and tolerance range of its various elements and finds expression in the mixed representation of polyhalobous, mesohalobous, and oligohalobous diatoms with stenohaline or euryhaline tendencies. The main constituent, however, comprises species of polyhalobous character with euryhaline inclination. Simonsen's ratings (see Table 1) show a halinity tolerance spread encompassing the meio-euryhaline, meso-euryhaline, and pleio-euryhaline subdivisions of the polyhalobous group in decreasing order with the highest species representation found in the 35 to ~20-17 halinity delineation.

Lowered surface water salinities can also be adduced from the prevalence of **Thalassiosira antarctica** whose salinity values (calculated mean 25.5‰, Northern Hemisphere) reflect the influence of melting ice (Hasle and Heimdal, 1968; Smayda, 1958) and from established optimal ratings for **Porosira glacialis** (25.9‰; Brunel, 1970) and **Detonula confervacea** (29.4‰; Brunel, 1970). A more recent optimal salinity range value of 15-30‰ for **Detonula confervacea** was inferred by Holt and Smayda (1974) from growth rate experiments. Salinity tolerance determinations show that the diatom-bearing sediment was deposited in a nearshore environment subject to lowered salinities. This inference is further strengthened by the presence of **Coscinodiscus lacustris**, a cold water stenotherm, indicating estuarine influence.

Paleobathymetry

Contrary to paleosalinity characterization, most diatoms indicate low reliability with regard to depth zonation. Determination of paleobathymetric conditions is based solely on the benthos/plankton ratio which provides

Table 2

Environmental aspects of the diatoms from a Pleistocene deposit near Cape Storm, Ellesmere Island

		Mode of living and substrate affinity									
		oceanic	neritic	littoral	Planktonic	benthic	epontic	epiphytic	episammic	epipelic	epilithic
	CENTRICAE										
	ACTINOCYCLUS Ehrenberg										
o-r	**Actinocyclus** spp.										
	BACTEROSIRA Gran.										
sd	**Bacterosira fragilis** (Gran) Gran		x		x						
	BIDDULPHIA Gray										
sd	**B. aurita** (Lyngb.) Bréb. et God.	x	x	x	x	x	x	x	x	x	
s	**B. aurita** var. **obtusa** (Kütz.) Hust.		x	x	x						
	COSCINODISCUS Ehrenberg										
o-r	**Coscinodiscus centralis** Ehr. (fragm.)	x	x		x	x	x				
o-r	**C. curvatulus** var. **kariana** Cleve & Grun.	x	x		x						
o-r	**C. curvatulus** var. **minor** (Ehr.) Grun.	x		x	x						
o-r	**C. divisius** Grun.	x	x	x	x						
o-r	**C. kützingii** A.S.		x	x	x	x					
o-r	**C. lacustris** var. **hyperborea** (Grun.) Rattr.		x	x	x						
o-r	**C. lacustris** var. **septentrionalis** Grun.	x	x	x	x						
	DETONULA Gran										
	D. confervacea (Cleve) Gran	x	x		x						
	HYALODISCUS Ehrenberg										
o-r	**H. laevis** Ehr.										
o-r	**H. scoticus** (Kütz.) Grun.		x	x	x	x		x			
o-r	**H. subtilis** Bail.	x	x	x	x			x			
	MELOSIRA Agardh										
s	**M. arctica** (Ehr.) Dickie		x	x	x	x					
s	**M. moniliformis** (O. Müller) Ag.		x	x	x	x	x	x	x		x
s	**M. nummuloides** (Dillw.) Ag.		x	x	x	x	x	x	x		x
	Melosira sp.										
	PODOSIRA Ehrenberg										
s	**P. hormoides** var. **arctica** (Cleve ex Cleve et Grun.) Hust.	x		x		x					
	Podosira sp.										
	POROSIRA Jørgensen										
s	**P. glacialis** (Grun.) Jørg.		x	x	x			x			
	RHIZOSOLENIA Ehrenberg										
o-r	**R. hebetata** fo. **semispina** (Hens.) Gran	x	x		x						
	SKELETONEMA Greville										
o-r	**S. costatum** (Grev.) Cleve		x		x						
	STEPHANODISCUS Ehrenberg										
o-r	**S. astraea** (Ehr.) Grun. in Cleve et Grun.				x			x			

		Mode of living and substrate affinity									
		oceanic	neritic	littoral	Planktonic	benthic	epontic	epiphytic	episammic	epipelic	epilithic
	CENTRICAE										
	CERATONEIS Ehrenberg										
o-r	**C. arcus** (Ehr.) Kütz. var. **linearis** Holmb. (fragm.)			x	x						
	COCCONEIS Ehrenberg										
s	**C. costata** Greg.			x		x	x	x	x	x	
s	**C. scutellum** Ehr.		x	x		x	x	x	x	x	
s	**C. scutellum** var. **stauroneiformis** W. Sm.			x		x	x	x	x		
	Cocconeis spp.										
	CYMBELLA Agardh										
o-r	**C. angustata** (W. Sm.) Cleve							x			
	DIPLONEIS Ehrenberg										
s	**D. bomboides** Cleve var. **media** (Grun. in Cleve et Grun.) Hust.			x		x		x			
o-r	**D. interrupta** (Kütz.) Cleve var.					x		x		x	
s	**D. smithii** (Bréb. in W. Sm.) Cleve			x		x	x	x	x	x	
s	**D. subcincta** (A.S.) Cleve			x		x					
	FRAGILARIA Lyngbye										
o-r	**F. pinnata** Ehr.			x	x	x	x		x	x	
o-r	**F. striatula** Lyngb.	x			x			x		x	
	Fragilaria spp.										
	GOMPHONEMA Agardh										
o-r	**G. geminatum** var. **sibirica** Grun.							x			
o-r	**G. kamtchaticum** Grun.							x			
o-r	**G. pseudoexiguum** Simonsen					x	x				
	GRAMMATOPHORA Ehrenberg										
o-r	**G. angulosa** Ehr.			x		x	x	x	x	x	
o-r	**G. arctica** Cleve			x							
	GYROSIGMA Hassall										
o-r	**G. arcticum** (Cleve) Cleve		x			x			x	x	
	LICMOPHORA Agardh										
o-r	**L. gracilis** var. **anglica** (Kütz.) Perag.	x		x			x	x		x	
	Licmophora spp.										
	NAVICULA Bory										
s	**N. cancellata** Donk.			x		x			x	x	
s	**N. cancellata** var. **apiculata** (Greg.) Perag.			x		x			x	x	
s	**N. cancellata** var. **subapiculata** Grun.			x		x			x	x	
o-r	**N. conoides** (Dillw.) Perag.			x	x	x		x			
s	**N. compressicauda** A.S.					x					
o-r	**N. clothensis** Greg.					x				x	
o-r	**N. clothensis** var. **striolata** Grun.					x				x	
s	**N. digitoradiata** (Greg.) Ralfs in Pritch.			x		x		x	x	x	
s	**N. directa** (W. Sm.) Ralfs in Pritch.			x	x	x	x			x	
s	**N. directa** var. **remota** Grun.			x	x	x	x			x	
s	**N. directa** var. **subtilis** (Greg.) Cleve			x	x	x	x			x	

	THALASSIOSIRA Cleve											
sd	**T. antarctica** Comb.	x	x		x							
sd	**T. constricta** Gaarder		x		x							
o-r	**T. eccentrica** (Greg.) Hasle	x		x	x							
s	**T. hyalina** (Grun. in Cleve et Grun.) Gran		x	x	x							
o-r	**T. kryophila** (Grun.) Jörg.		x		x							
o-r	**T. nordenskiöldii** Cleve		x	x	x							
	Thalassiosira spp.											
	PENNATAE											
	ACHNANTHES Bory											
o-r	**A. arctica** var. **baltica** Grun.											
s	**A. brevipes** Agardh			x	x	x	x	x	x	x	x	
o-r	**A. brevipes** var. **minor** Perag.											
s	**A. delicatula** (Kütz.) Grun. in Cleve et Grun.							x		x		
s	**A. groenlandica** (Cleve) Grun. in Cleve et Grun.			x	x		x	x	x		x	
o-r	**A. hauckiana** Grun.			x				x		x	x	
o-r	**A. polaris** Gstr.											
	Achnanthes spp.											
	AMPHIPLEURA Kützing											
s	**A. rutilans** (Trent. ex Roth) Cleve			x		x	x	x	x	x	x	
	AMPHIPRORA Ehrenberg											
o-r	**A. gigantea** var. **septentrionalis** (Grun.) Cleve					x						
	AMPHORA Ehrenberg											
o-r	**A. scutiuscula** Kütz.					x			x	x		
s	**A. angusta** Greg.			x		x			x	x		
s	**A. angusta** var. **arctica** Cleve			x		x						
s	**A. angusta** var. **oblongella** (Grun.) Cleve					x						
o-r	**A. angustissima** Heid. & Kolb.					x						
s	**A. caterinaria** Choln.					x						
s	**A. crassa** Greg.					x		x	x	x		
s	**A. cymbifera** Greg.			x		x			x	x		
s	**A. graeffeana** Hend.											
s	**A. holsatica** Hust.					x		x	x	x		
o-r	**A. interrupta** (non Pant.) Heid. & Kolb.					x						
s	**A. laevis** var. **laevissima** (Greg.) Cleve			x		x			x	x		
s	**A. libyca** var. **baltica** (Brander) Cleve-Euhler					x			x			
o-r	**A. lindbergii** Cleve-Euler					x			x			
o-r	**A. lineolata** Ehr.			x	x	x			x	x		
o-r	**A. lineolata** var. **plicata** (Greg.) A. Cleve					x						
o-r	**A. macilenta** Greg.					x			x	x		
o-r	**A. novae caledoniae** Grun.					x						
s	**A. oblonga** Greg.					x						
o-r	**A. ocellata** Donk.					x			x	x		
o-r	**A. ostrearia** var. **vitrea** (Cleve) Cleve			x		x	x		x			
s	**A. ovalis** var. **libyca** (Ehr.) Cleve			x		x	x		x	x	x	
s	**A. proteus** Greg.			x		x	x	x	x	x		
s	**A. proteus** var. **oculata** Perag.			x		x	x		x	x		
o-r	**A. scabriuscula** Cleve & Grove					x						
o-r	**A. wisei** (Sal.) Sim.					x						
o-r	**A. weissflogii** A.S. in Schmidt et al.			x		x						
	Amphora spp.											
	CALONEIS Cleve											
o-r	**C. brevis** (Greg.) Cleve			x		x			x	x		
s	**C. liber** (W. Smith) Cleve					x		x	x	x		
o-r	**C. liber** var. **elongata** Grun.					x		x	x	x		
	Caloneis sp.											
	CAMPYLODISCUS Ehrenberg											
o-r	**C. angularis** Greg.			x		x		x				

o-r	**N. dissipata** Hust.					x						
s	**N. distans** (W. Sm.) Ralfs in Pritch.			x	x	x			x	x		
o-r	**N. finnmarchica** (Cl. & Grun.) Cleve			x		x		x	x	x		
o-r	**N. fercipata** Grev.			x		x		x	x	x		
o-r	**N. gelida** Grun.					x				x		
sd	**N. grevillei** (Ag.?) Heib.			x		x	x	x				
o-r	**N. litoricola** Hust.					x			x	x		
o-r	**N. lyra** var. **atlantica** A.S.		x	x		x			x	x		
o-r	**N. palpebralis** var. **semiplena** (Greg.) Cleve			x		x			x	x		
o-r	**N. pennata** A.S.					x						
o-r	**N. reichardtii** var. **tschukotschorum** Cleve			x		x						
s	**N. rostellata** Kütz.			x		x			x	x		
d	**N. subfossilis** n. sp.					x						
o-r	**N. subinflata** Grun.			x		x						
o-r	**N. superba** Cleve					x						
o-r	**N. transitans** Cleve			x		x						
	Navicula spp.											
	NITZSCHIA Hassall											
o-r	**N. angularis** W. Sm.			x	x							
o-r	**N. cylindrus** (Grun.) Hasle		x	x	x				x			
s	**N. grunowii** Hasle		x		x	x	x					
o-r	**N. hybrida** Grun.					x						
o-r	**N. marginulata** Grun. var. **minuta**			x		x						
o-r	**N. prolonga** Cleve					x						
o-r	**N. recta** Hantzsch ex Rabh.			x		x						
o-r	**N. sigma** (Kütz.) W. Sm.			x		x	x	x		x		
s	**N. socialis** Greg.			x					x			
s	**N. socialis** var. **baltica** Grun.			x								
	Nitzschia spp.											
	PINNULARIA Ehrenberg											
o-r	**P. ambigua** Cleve			x		x			x	x		
o-r	**P. quadratarea** (A.S.) Cleve					x			x	x		
o-r	**P. quadratarea** var. **constricta** (Gstr.) Heid.					x			x	x		
	PLEUROSIGMA W. Smith											
o-r	**P. longum** Cleve			x		x						
o-r	**P. strigosum** W. Sm.					x			x	x		
	SURIRELLA Turpin											
o-r	**Surirella** sp. (fragment)											
	SYNEDRA Ehrenberg											
s	**S. camtschatica** Grun.			x				x	x	x		
s	**S. camtschatica** var. **finnmarchica** Cleve et Grun.			x				x	x	x		
s	**S. tabulata** (Ag.) Kütz.			x		x		x	x	x		
	Synedra spp.											
	TABELLARIA Ehrenberg											
o-r	**T. fenestrata** (Lyngb.) Kütz.		x	x	x			x				
	THALASSIONEMA Grunow											
o-r	**T. nitzschioides** (Grun.) V.H.		x	x	x							
	THALASSIOTHRIX Cleve & Grunow											
o-r	**Thalassiothrix** sp.											
	TRACHYNEIS Cleve											
s	**T. aspera** (Ehr.) Cleve			x	x	x	x		x	x		
s	**T. aspera** var. **media** (Grun.) Cleve			x	x	x	x		x	x		
	TROPIDONEIS Cleve											
o-r	**Tropidoneis** sp.											
	MISC.											
	DISTEPHANUS Stöhr											
o-r	**D. octonarius** (Ehr.) Defl. var. **octonarius**	x			x							

Table 3

Distributional aspects of the diatoms from a Pleistocene deposit near Cape Storm, Ellesmere Island

		Climatic/geographic affinity			Present distribution		Ice association	
		arctic	boreal	cosmopolitan	Arctic	Ellesmere Island	Arctic	Antarctic
	CENTRICAE							
	ACTINOCYCLUS Ehrenberg							
o-r	**Actinocyclus** spp.							
	BACTEROSIRA Gran.							
sd	**Bacterosira fragilis** (Gran) Gran	x			x	x	x	
	BIDDULPHIA Gray							
sd	**B. aurita** (Lyngb.) Bréb. et God.			x	x	x	x	
s	**B. aurita** var. **obtusa** (Kütz.) Hust.	x	x		x			
	COSCINODISCUS Ehrenberg							
o-r	**Coscinodiscus centralis** Ehr. (fragm.)			x	x	x	x	
o-r	**C. curvatulus** var. **kariana** Cleve & Grun.	x	x		x	x	x	
o-r	**C. curvatulus** var. **minor** (Ehr.) Grun.			x	x		x	
o-r	**C. divisius** Grun.							
o-r	**C. kützingii** A.S.			x	x		x	
o-r	**C. lacustris** var. **hyperborea** (Grun.) Rattr.	x	x		x		x	
o-r	**C. lacustris** var. **septentrionalis** Grun.			x	x		x	
	DETONULA Gran							
	D. confervacea (Cleve) Gran	x	x		x			
	HYALODISCUS Ehrenberg							
o-r	**H. laevis** Ehr.			x	x		x	
o-r	**H. scoticus** (Kütz.) Grun.			x	x	x	x	
o-r	**H. subtilis** Bail.			x	x		x	
	MELOSIRA Agardh							
s	**M. arctica** (Ehr.) Dickie	x			x	x	x	
s	**M. moniliformis** (O. Müller) Ag.			x	x		x	
s	**M. nummuloides** (Dillw.) Ag.			x	x	x	x	
	Melosira sp.							
	PODOSIRA Ehrenberg							
s	**P. hormoides** var. **arctica** (Cleve ex Cleve et Grun.) Hust.	x			x	x	x	
	Podosira sp.							
	POROSIRA Jörgensen							
s	**P. glacialis** (Grun.) Jörg.	x	x		x	x	x	
	RHIZOSOLENIA Ehrenberg							
o-r	**R. hebetata** fo. **semispina** (Hens.) Gran			x	x	x	x	x
	SKELETONEMA Greville							
o-r	**S. costatum** (Grev.) Cleve			x			x	
	STEPHANODISCUS Ehrenberg							
o-r	**S. astraea** (Ehr.) Grun. in Cleve et Grun.		x	x	x			

		Climatic/geographic affinity			Present distribution		Ice association	
		arctic	boreal	cosmopolitan	Arctic	Ellesmere Island	Arctic	Antarctic
	CERATONEIS Ehrenberg							
o-r	**C. arcus** (Ehr.) Kütz. var. **linearis** Holmb. (fragm.)			x	x			
	COCCONEIS Ehrenberg							
s	**C. costata** Greg.			x	x	x	x	
s	**C. scutellum** Ehr.			x	x	x	x	x
s	**C. scutellum** var. **stauroneiformis** W. Sm.			x	x	x	x	
	Cocconeis spp.							
	CYMBELLA Agardh							
o-r	**C. angustata** (W. Sm.) Cleve				x			
	DIPLONEIS Ehrenberg							
s	**D. bomboides** Cleve var. **media** (Grun. in Cleve et Grun.) Hust.			x	x	x		
o-r	**D. interrupta** (Kütz.) Cleve var.			x	x	x		
s	**D. smithii** (Bréb. in W. Sm.) Cleve			x	x	x	x	
s	**D. subcincta** (A.S.) Cleve			x	x			
	FRAGILARIA Lyngbye							
o-r	**F. pinnata** Ehr.			x	x		x	
o-r	**F. striatula** Lyngb.	x		x	x	x	x	
	Fragilaria spp.							
	GOMPHONEMA Agardh							
o-r	**G. geminatum** var. **sibirica** Grun.							
o-r	**G. kamtchaticum** Grun.	x			x		x	
o-r	**G. pseudoexiguum** Simonsen							
	GRAMMATOPHORA Ehrenberg							
o-r	**G. angulosa** Ehr.			x	x		x	
o-r	**G. arctica** Cleve	x			x	x	x	x
	GYROSIGMA Hassall							
o-r	**G. arcticum** (Cleve) Cleve	x			x		x	
	LICMOPHORA Agardh							
o-r	**L. gracilis** var. **anglica** (Kütz.) Perag.			x	x			
	Licmophora spp.							
	NAVICULA Bory							
s	**N. cancellata** Donk.			x	x		x	
s	**N. cancellata** var. **apiculata** (Greg.) Perag.							
s	**N. cancellata** var. **subapiculata** Grun.				x			
o-r	**N. comoides** (Dillw.) Perag.			x	x			
s	**N. compressicauda** A.S.				x			
o-r	**N. cluthensis** Greg.				x		x	
o-r	**N. cluthensis** var. **striolata** Grun.							
s	**N. digiteradiata** (Greg.) Ralfs in Pritch.			x	x	x	x	
s	**N. directa** (W. Sm.) Ralfs in Pritch.			x	x		x	x
s	**N. directa** var. **remota** Grun.			x	x		x	
s	**N. directa** var. **subtilis** (Greg.) Cleve			x	x		x	
o-r	**N. dissipata** Hust.							

	THALASSIOSIRA Cleve							
sd	T. antarctica Comb.	x			x			x
sd	T. constricta Gaarder	x						
o-r	T. ecentrica (Greg.) Hasle			x	x		x	x
s	T. hyalina (Grun. in Cleve et Grun.) Gran	x			x		x	x
o-r	T. leryophila (Grun.) Jörg.	x			x		x	
o-r	T. nordenskiöldii Cleve	x	x		x	x	x	
	Thalassiosira spp.							
	PENNATAE							
	ACHNANTHES Bory							
o-r	A. arctica var. baltica Grun.	x						
s	A. brevipes Agardh			x	x	x	x	x
o-r	A. brevipes var. minor Perag.			x				
s	A. delicatula (Kütz.) Grun. in Cleve et Grun.			x	x		x	
s	A. groenlandica (Cleve) Grun. in Cleve et Grun.			x	x	x		
o-r	A. hauckiana Grun.			x				
o-r	A. polaris Østr.	x			x		x	
	Achnanthes spp.							
	AMPHIPLEURA Kützing							
s	A. rutilans (Trent. ex Roth) Cleve			x	x		x	x
	AMPHIPRORA Ehrenberg							
o-r	A. gigantea var. septentrionalis (Grun.) Cleve	x			x		x	
	AMPHORA Ehrenberg							
o-r	A. acutiuscula Kütz.			x				
s	A. angusta Greg.			x	x		x	
s	A. angusta var. arctica Cleve	x						
s	A. angusta var. oblongella (Grun.) Cleve	x	x					
o-r	A. angustissima Heid. & Kolb.							
s	A. catarinaria Choln.							
s	A. crassa Greg.			x	x		x	
s	A. cymbifera Greg.			x	x			
s	A. greffeana Hend.	x						
s	A. holsatica Hust.	x						
o-r	A. interrupta (non Pant.) Heid. & Kolb.							
s	A. laevis var. laevissima (Greg.) Cleve			x	x		x	
s	A. libyca var. baltica (Brander) Cleve-Euhler	x	x					
o-r	A. lindbergii Cleve-Euler							
o-r	A. lineolata Ehr.			x	x			
o-r	A. lineolata var. plicata (Greg.) A. Cleve				x			
o-r	A. macilenta Greg.				x			
o-r	A. novae caledoniae Grun.				x			
s	A. oblonga Greg.				x			
o-r	A. ocellata Donk.			x	x		x	
o-r	A. ostrearia var. vitrea (Cleve) Cleve			x	x			
s	A. ovalis var. libyca (Ehr.) Cleve				x			x
s	A. proteus Greg.			x	x	x	x	
s	A. proteus var. oculata Perag.			x	x			
o-r	A. scabriuscula Cleve & Grove							
o-r	A. wisei (Sal.) Sim.			x				
o-r	A. weissflogii A.S. in Schmidt et al.				x			
	Amphora spp.							
	CALONEIS Cleve							
o-r	C. brevis (Greg.) Cleve			x	x		x	
s	C. liber (W. Smith) Cleve			x	x		x	
o-r	C. liber var. elongata Grun.			x	x			
	Caloneis sp.							
	CAMPYLODISCUS Ehrenberg							
o-r	C. angularis Greg.			x	x			

s	N. distans (W. Sm.) Ralfs in Pritch.			x	x		x	x
o-r	N. finnmarchica (Cl. & Grun.) Cleve			x	x			
o-r	N. forcipata Grev.			x	x		x	
o-r	N. gelida Grun.				x		x	
sd	N. grevillei (Ag.?) Heib.			x	x			
o-r	N. litoricola Hust.							
o-r	N. lyra var. atlantica A.S.			x	x		x	
o-r	N. palpebralis var. semiplena (Greg.) Cleve			x	x			
o-r	N. pennata A.S.							
o-r	N. reichardtii var. tschukitscherum Cleve	x			x			
s	N. rostellata Kütz.	x	x		x		x	
d	N. subfossilis n. sp.	x			x	x		
o-r	N. subinflata Grun.	x			x		x	
o-r	N. superba Cleve	x			x		x	
o-r	N. transitans Cleve	x	x		x		x	
	Navicula spp.							
	NITZSCHIA Hassall							
o-r	N. angularis W. Sm.			x	x	x	x	
o-r	N. cylindrus (Grun.) Hasle	x			x		x	x
s	N. grunowii Hasle	x			x	x	x	
o-r	N. hybrida Grun.	x			x		x	
o-r	N. marginulata Grun. var. minuta	x			x	x	x	
o-r	N. praelonga Cleve	x			x			
o-r	N. recta Hantzsch ex Rabh.	x			x		x	
o-r	N. sigma (Kütz.) W. Sm.	x		x	x	x	x	
s	N. socialis Greg.	x	x		x			
s	N. socialis var. baltica Grun.	x			x		x	
	Nitzschia spp.							
	PINNULARIA Ehrenberg							
o-r	P. ambigua Cleve			x	x	x	x	
o-r	P. quadratarea (A.S.) Cleve			x	x		x	
o-r	P. quadratarea var. constricta (Østr.) Heid.			x	x		x	
	PLEUROSIGMA W. Smith							
o-r	P. longum Cleve	x	x		x	x	x	
o-r	P. strigosum W. Sm.			x	x		x	
	SURIRELLA Turpin							
o-r	Surirella sp. (fragment)							
	SYNEDRA Ehrenberg							
s	S. camtschatica Grun.	x			x	x	x	
s	S. camtschatica var. finnmarchica Cleve et Grun.	x			x	x	x	
s	S. tabulata (Ag.) Kütz.			x	x	x	x	
	Synedra spp.							
	TABELLARIA Ehrenberg							
o-r	T. fenestrata (Lyngb.) Kütz.			x	x	x	x	
	THALASSIONEMA Grunow							
o-r	T. nitzschioides (Grun.) V.H.			x	x	x	x	
	THALASSIOTHRIX Cleve & Grunow							
o-r	Thalassiothrix sp.							
	TRACHYNEIS Cleve							
s	T. aspera (Ehr.) Cleve			x	x	x	x	
s	T. aspera var. media (Grun.) Cleve			x	x			
	TROPIDONEIS Cleve							
o-r	Tropidoneis sp.							
	M I S C.							
	DISTEPHANUS Stöhr							
o-r	D. octonarius (Ehr.) Defl. var. octonarius				x			

only a rough estimation of depth. A more precise bathymetric delineation may be derived from foraminiferal depth distribution analyses. Nevertheless, the preponderance of benthic and epiphytic forms and the low frequency of species comprising the holoplanktonic component suggest a shallow marine environment. Nearshore waters and coastal realm are also indicated by the high incidence of meroplanktonic forms.

CONCLUSIONS

From compositional and autecological analyses, the following generalizations emerge:

1. the pronounced arctic nature of the diatom flora as manifested by the presence of bipolar species, arctic endemic forms, cryoplanktonic elements, circumpolar species, and stenothermal cold water diatoms,
2. coastal proximity and depth restriction as expressed by the prevalence of littoral-neritic species with only minor oceanic elements, and
3. low salinity surface waters as evidenced by the euryhaline character of the polyhalobous component.

In summary, the floristic composition of the Pleistocene thanatocoenosis indicates sedimentation in a coastal marine biotope, subject to lowered salinities due to melting sea ice and runoff. This paleoenvironmental interpretation corroborates Blake's (1980) conclusion of a "shallow marine environment and frigid water conditions". Application of a multidisciplinary approach, including analysis of other biological components, will further strengthen and refine paleoclimatological reconstruction.

Considering the various limitations discussed earlier, the initial value of this investigation will have to remain principally one of floristic documentation. The somewhat general nature of the conclusion based on diatom analysis argues for the need of intensive taxonomic studies and of detailed investigations into the dynamics of arctic marine littoral biocoenoses. This would provide a sound basis for a valid assessment of fossil diatom assemblages and aid in the elucidation and reconstruction of Pleistocene environments in arctic regions.

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APPENDIX

Alternative synonymy according to Van Landingham (1967, 1968, 1975, 1978)

SYNONYMY	
in text	Van Landingham
Amphora acutiuscula Kützing	**Amphora coffeaeformis** var. **acutiuscula** (Kützing) Hustedt
Amphora angusta var. **arctica** Cleve	**Amphora angusta** var. **oblongella** (Grunow) Cleve
Amphora cymbiformis Gregory	**Amphora terroris** Ehrenberg
Amphora novae caledoniae Grunow	**Amphora ostrearia** var. **vitrea** (Cleve) Cleve
Amphora oblonga Gregory	**Amphora robusta** Gregory
Amphora scabriuscula Cleve & Grove	**Navicula scabriuscula** (Cleve & Grove) Mereschkowsky
Amphora ventricosa (Gregory) Cleve	**Amphora angusta** var. **ventricosa** (Gregory) Cleve
Coscinodiscus divisius Grunow	**Actinocyclus cholnokyi** Van Landingham
Navicula reichardtii var. **tschuktschorum** Cleve	**Diploneis reichardtii** var. **tschuktschorum**(Cleve) Heiden in Heiden et Kolbe
Pleurosigma strigosum W. Smith	**Pleurosigma angulatum** var. **strigosum** (W. Smith) Van Heurck

PLATE 1

(Magnification x800)

Figure 1-5. **Diploneis bomboides** var. **media** (Grunow in Cleve et Grunow) Hustedt

6,7. **Diploneis interrupta** (Kützing) Cleve

8-10. **Diploneis subcincta** (A. Schmidt) Cleve

11-20. **Diploneis smithii** (Brébisson in W. Smith) Cleve

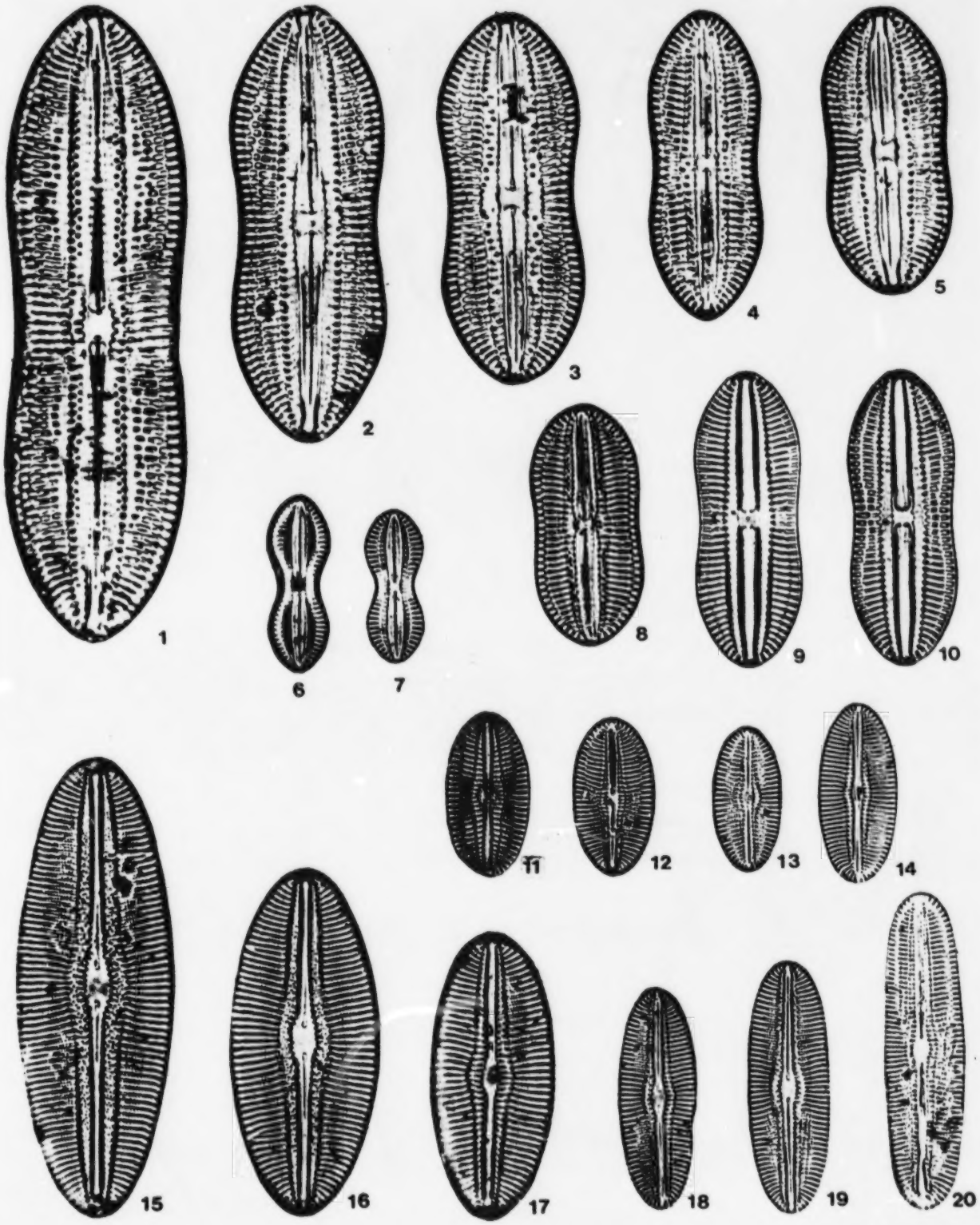
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PLATE 2

(Magnification x800)

Figure	1-7.	**Amphora proteus** var. **oculata** Peragallo et Peragallo
	8,9.	**Amphora ovalis** var. **libyca** (Ehrenberg) Cleve
	10,11.	**Amphora** spp.
	12-15.	**Amphora libyca** var. **baltica** (Brander) A. Cleve
	16,17.	**Amphora** spp.
	18.	**Amphora proteus** Gregory
	19.	**Amphora proteus** var. **oculata** Peragallo et Peragallo
	20.	**Amphora libyca** var. **baltica** (Brander) Cleve-Euler
	21-26.	**Amphora ovalis** var. **libyca** (Ehrenberg) Cleve
	27-29.	**Amphora lindbergii** Cleve-Euler
	30-33.	**Amphora** spp.
	34-36.	**Amphora oblonga** Gregory
	37,38.	**Amphora ovalis** var. **libyca** (Ehrenberg) Cleve
	39,40.	**Amphora** spp.
	41.	**Amphora proteus** Gregory

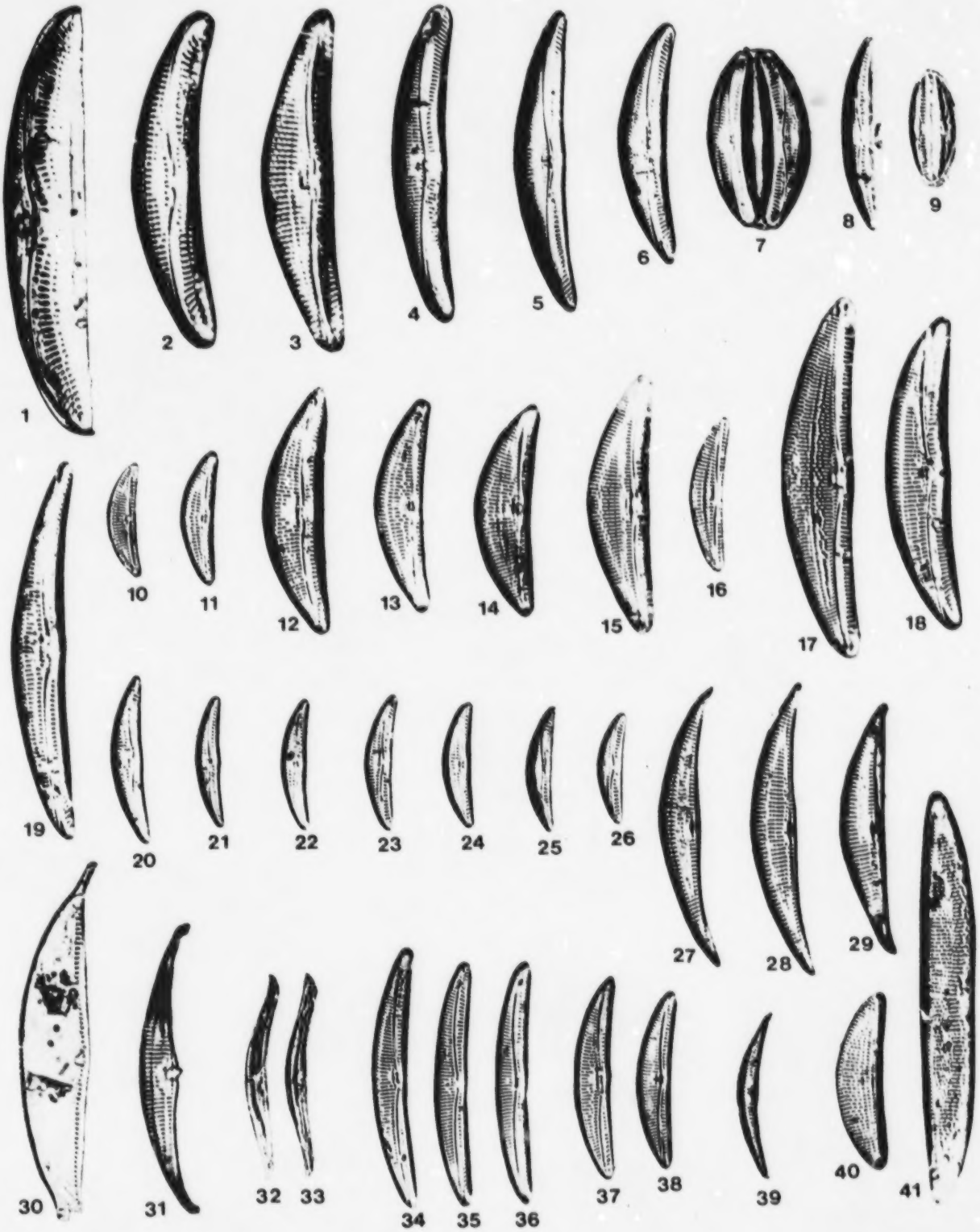
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PLATE 3

(Magnification x800)

Figure	1-3.	**Amphora** spp.
	4,5.	**Amphora scabriuscula** Cleve & Grove
	6,7.	**Amphora wisei** (Salah) Simonsen
	8-10.	**Amphora weissflogii** A. Schmidt in Schmidt et al.
	11.	**Amphora interrupta** (non Pant.) Heiden & Kolbe
	12.	**Amphora ostrearis** var. **vitrea** (Cleve) Cleve
	13-15.	**Amphora** spp.
	16-18.	**Amphora catarinaria** Cholnoky
	19-22.	**Amphora cymbifera** Gregory
	23,24.	**Amphora angustissima** Heiden & Kolbe
	25-27.	**Amphora novae caledoniae** Grunow

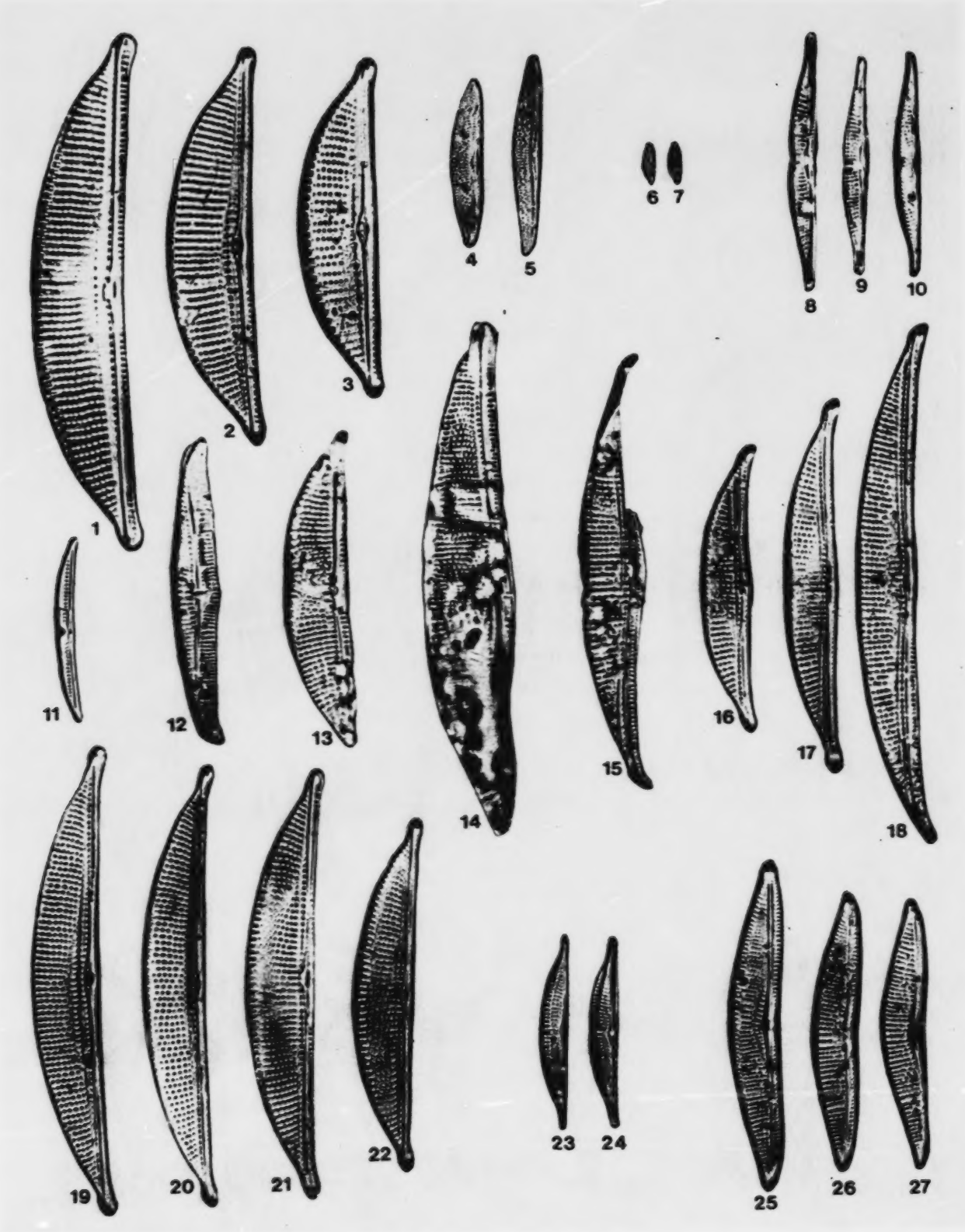
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PLATE 4

(Magnification x800)

Figure	1-7.	**Amphora angusta** Gregory
	8,9.	**Amphora ventricosa** (Gregory) Cleve
	10-12.	**Amphora angusta** var. **arctica** Cleve
	13.	**Amphora** sp.
	14-16.	**Amphora crassa** Gregory
	17-27.	**Amphora** spp.
	28-33.	**Amphora graeffeana** Hendey

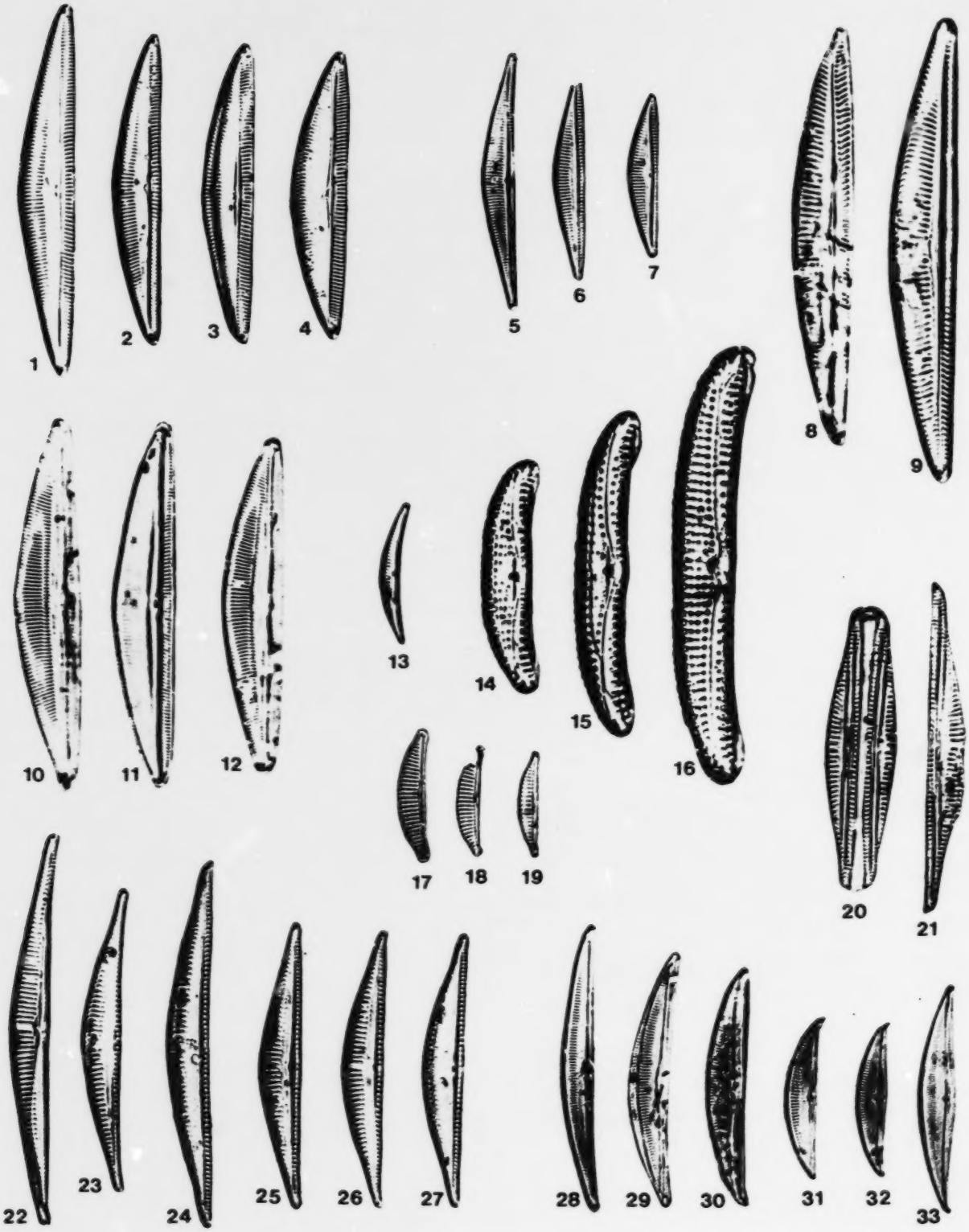
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PLATE 5

(Magnification x800)

Figure 1-4. **Amphora** sp.

5,6. **Amphora** sp.

7-11. **Amphora** sp.

12-15. **Amphora** sp.

16. **Amphora holsatica** Hustedt

17. **Amphora** sp.

18. **Amphora** sp.

19. **Amphora macilenta** Gregory

20. **Amphora** sp.

21. **Amphora acutiuscula** Kützing

22. **Navicula** sp.

23. Undetermined form

24-28. **Navicula** spp.

29. **Fragilaria striatula** Lyngbye

30,31. **Gomphonema pseudoexiguum** Simonsen

32. **Fragilaria pinnata** Ehrenberg

33. **Gomphonema geminatum** var. **sibirica** Grunow

34. Undetermined form

35. Undetermined form

36,37. **Gomphonema kamtschaticum** Grunow

38-40. **Tabellaria fenestrata** (Lyngbye) Kützing

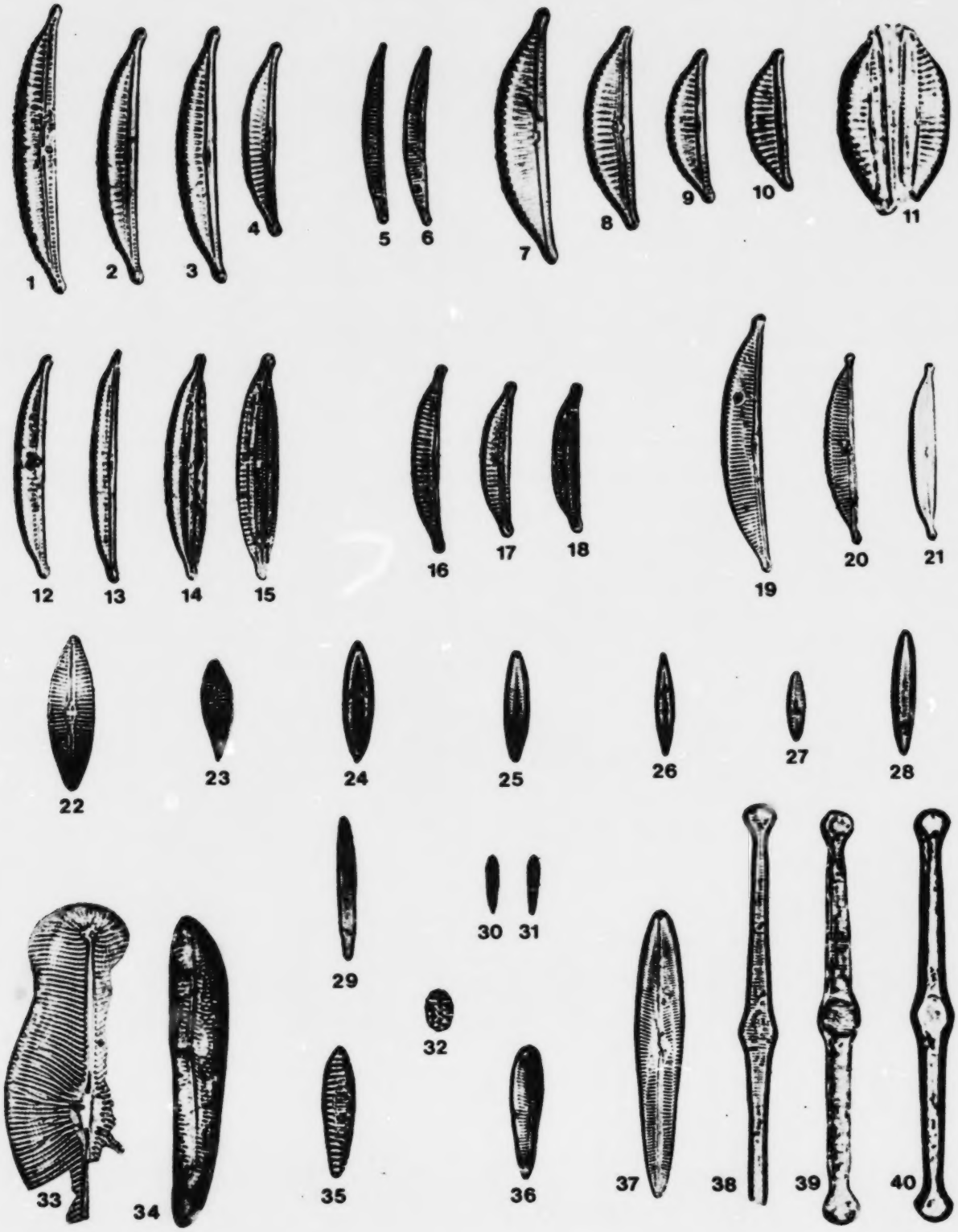
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PLATE 6

(Magnification x800)

Figure 1-4. **Navicula directa** (W. Smith) Ralfs in Pritchard

5. **Navicula directa** var. **remota** Grunow

6. **Navicula** sp.

7-9. **Navicula** sp.

10. **Achnanthes** sp. (teratological form)

11,12. **Navicula subinflata** Grunow

13. **Navicula** sp.

14. **Navicula** sp.

15. **Navicula** sp.

16. **Caloneis brevis** (Gregory) Cleve

17. **Pinnularia** sp.

18. **Caloneis** sp.

19. **Navicula** sp.

20-22. **Caloneis liber** (W. Smith) Cleve

23-25. **Pinnularia quadratarea** (A. Schmidt) Cleve

26. **Pinnularia quadratarea** var. **constricta** (Østrup) Heiden

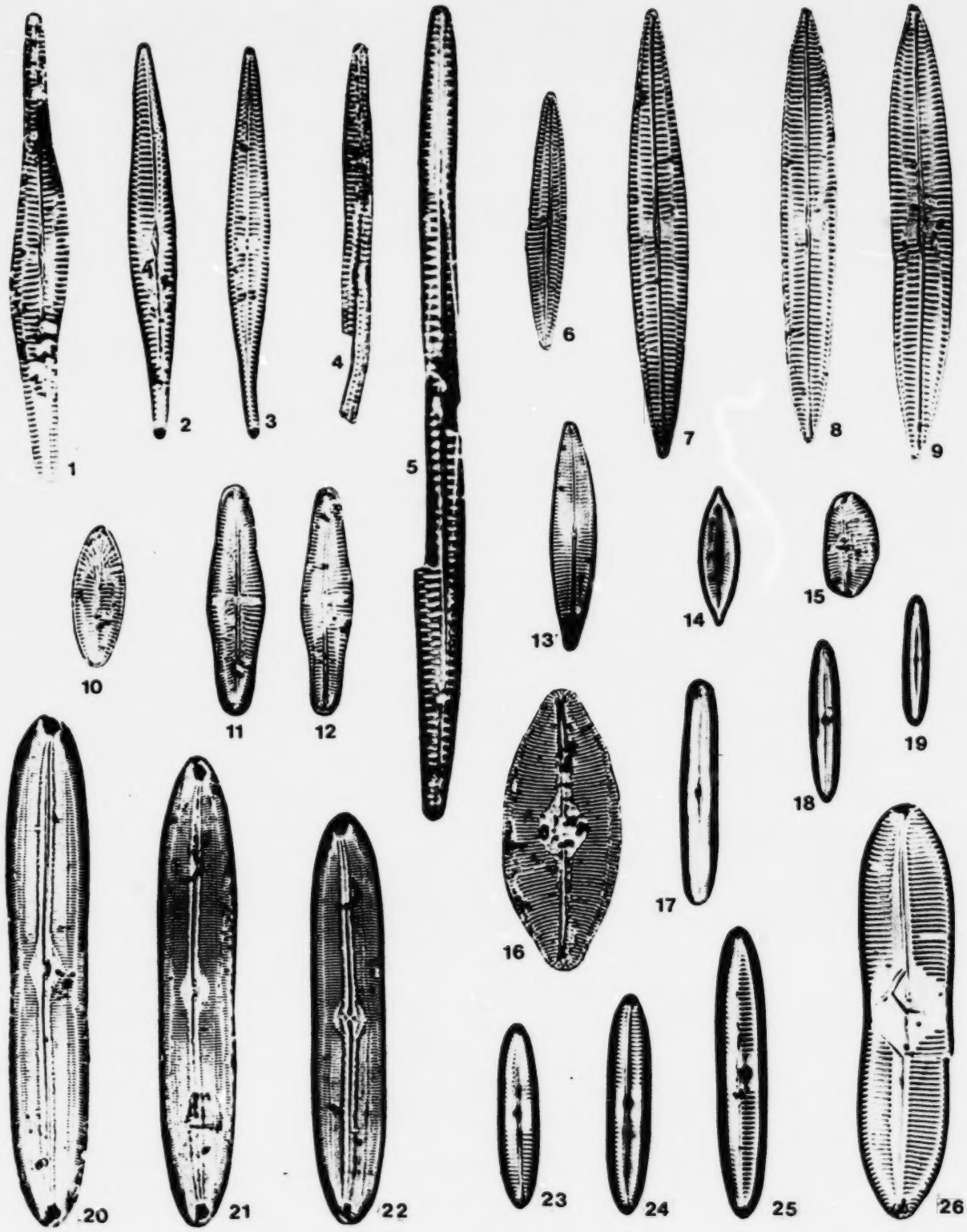
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PLATE 7

(Magnification x800)

Figure 1-5. **Navicula** spp.

6-9. **Navicula directa** var. **remota** Grunow

10-11. **Navicula directa** var. **subtilis** (Gregory) Cleve

12,13. **Navicula** sp.

14-18. **Navicula distans** (W. Smith) Ralfs in Pritchard

19-22. **Navicula directa** (W. Smith) Ralfs in Pritchard

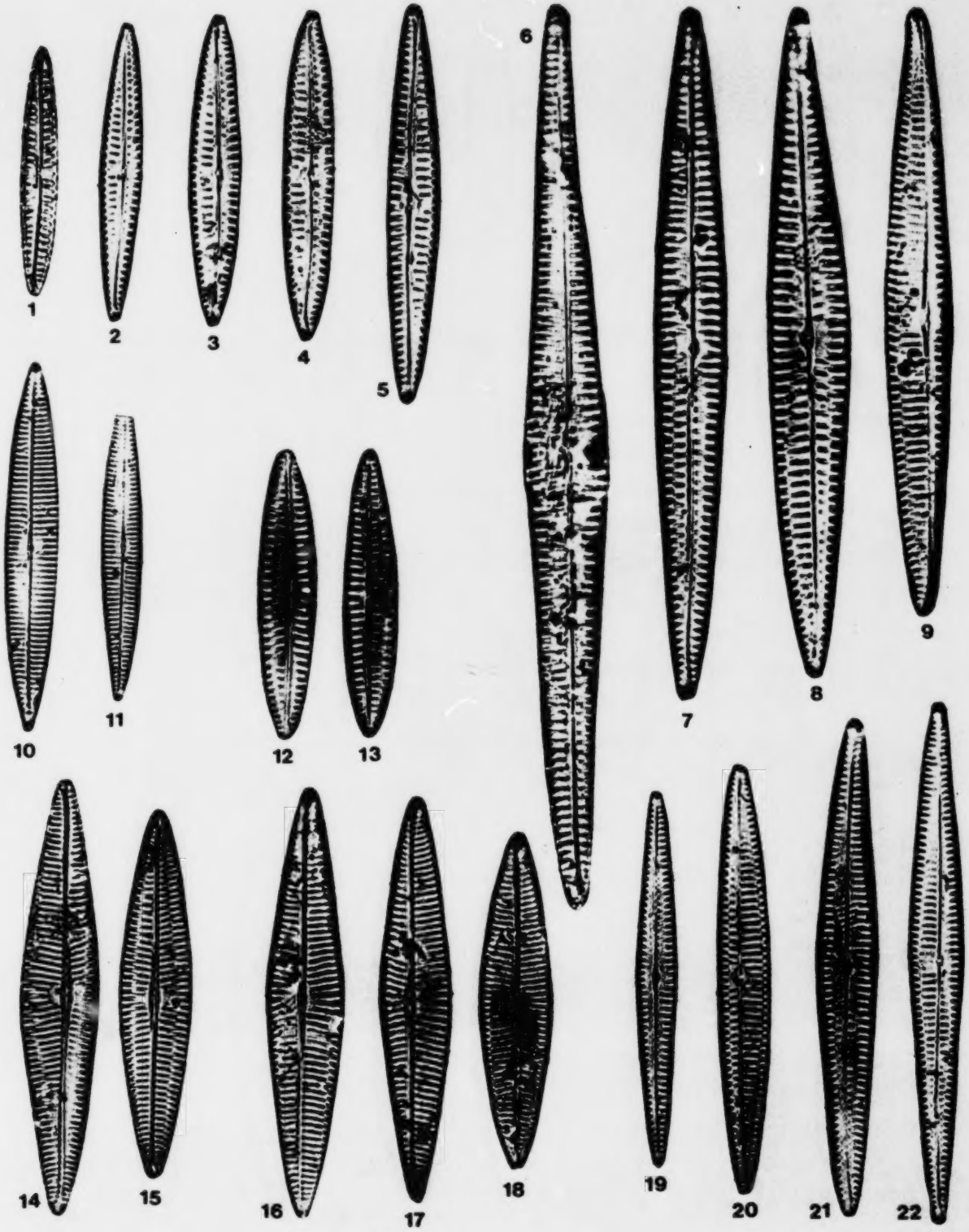
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PLATE 8

(Magnification x800)

Figure 1-6. **Navicula digitoradiata** (Gregory) Ralfs in Pritchard

7-10. **Navicula rostellata** Kützing

11-12. **Navicula cancellata** var. **subapiculata** Grunow

13,14. **Navicula cancellata** Donkin

15,16. **Navicula** sp.

17-20. **Navicula** spp.

21,22. **Navicula** sp.

23-25. **Navicula compressicauda** A. Schmidt

26-30. **Navicula cancellata** Donkin

31-35. **Navicula cancellata** var. **apiculata** (Gregory) Peragallo et Peragallo

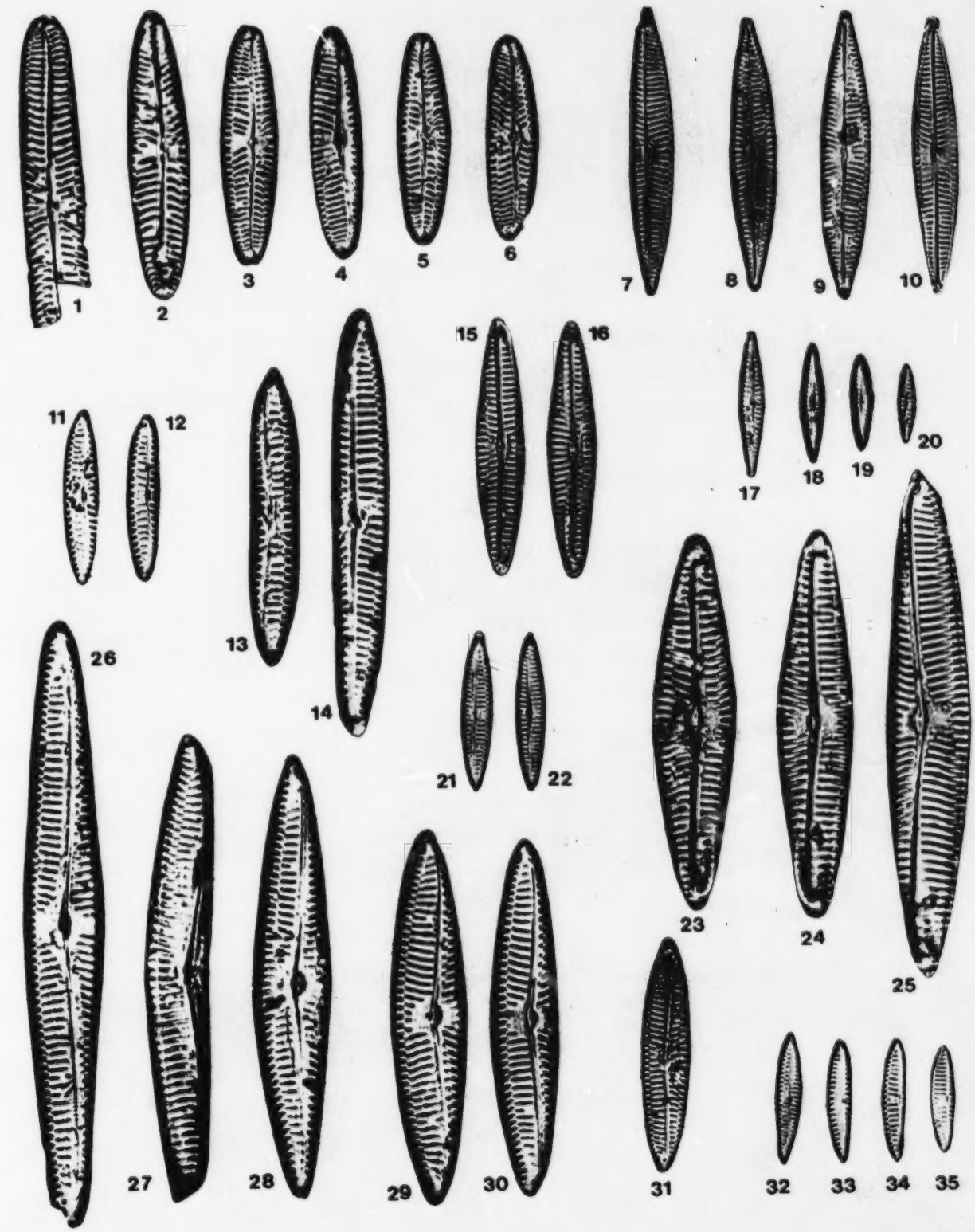
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PLATE 9

(Magnification x800)

Figure 1-5. **Navicula subfossilis** spec. nov.

6. **Navicula** sp.

7. **Navicula transitans** Cleve

8,9. **Navicula superba** Cleve

10-11. **Navicula finnmarchica** (Cleve & Grunow) Cleve

12,13. **Navicula comoides** (Dillwyn) Peragallo et Peragallo

14. **Cymbella angustata** (W. Smith) Cleve

15,16. **Navicula** spp.

17. **Navicula grevillei** (Agardh) Heiberg

18-20. **Navicula cluthensis** Gregory

21. **Navicula cluthensis** var. **striolata** Grunow

22. **Navicula** sp.

23. **Navicula litoricola** Hustedt

24. **Navicula lyra** var. **atlantica** A. Schmidt

27-29. **Navicula reichardtii** var. **tschuktschorum** Cleve

30-32. **Navicula grevillei** (Agardh) Heiberg

33-35. **Navicula** sp.

36,37. **Amphipleura rutilans** (Trentepohl ex Roth) Cleve

38,39. **Navicula palpebralis** var. **semiplena** (Gregory) Cleve

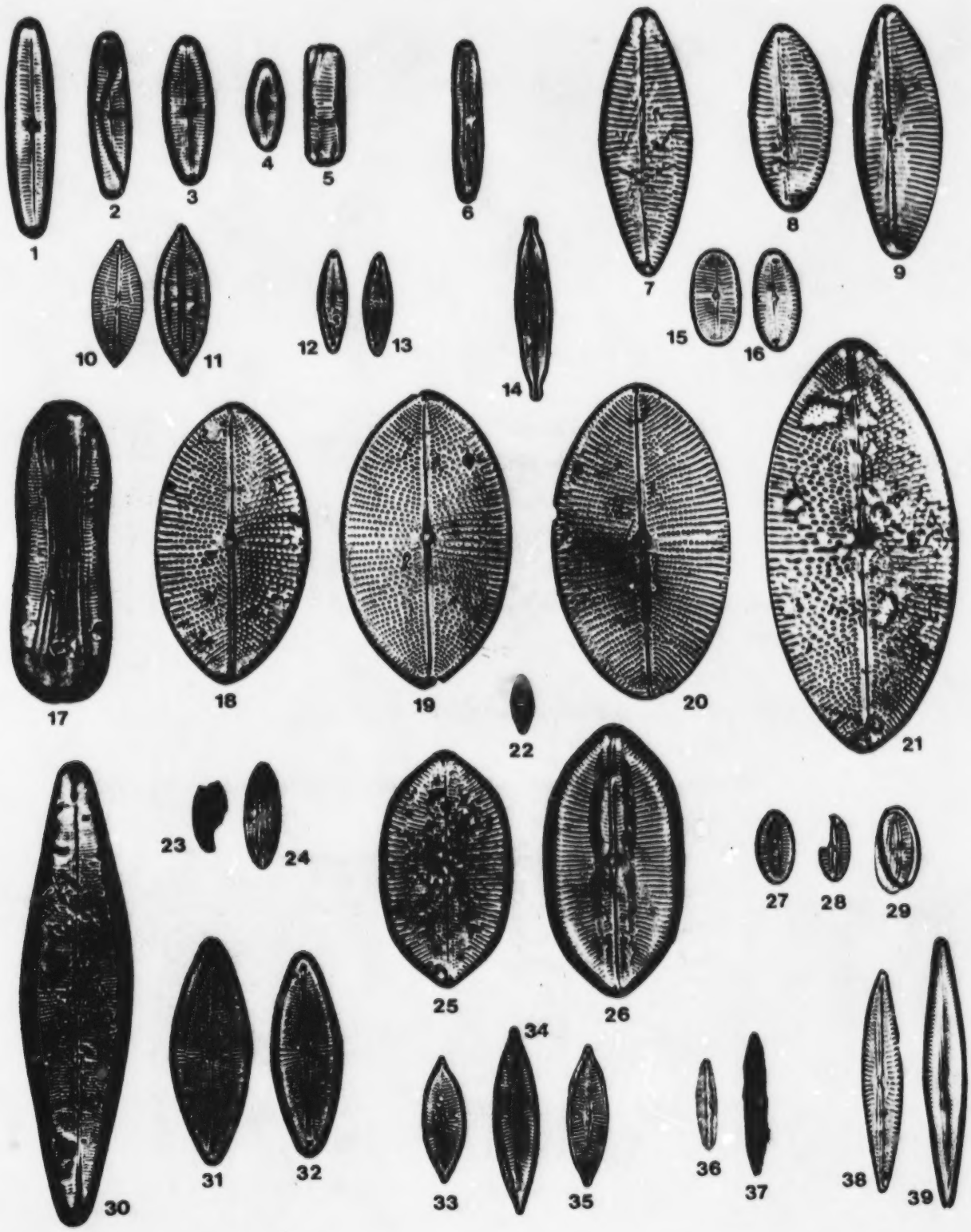
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PLATE 10

(Magnification x800)

Figure 1. **Achnanthes brevipes** Agardh

2. **Achnanthes arctica** var. **baltica** Grunow

3-5. **Cocconeis scutellum** Ehrenberg

6,7. **Cocconeis** spp.

8-11. **Cocconeis costata** Gregory

12. **Cocconeis scutellum** var. **stauroneiformis** W. Smith

13. **Cocconeis costata** Gregory

14-15. **Achnanthes** sp.

16-18. **Achnanthes groenlandica** (Cleve) Grunow in Cleve et Grunow (raphe valve)

19,20. **Cocconeis** spp.

21-23. **Achnanthes groenlandica** (Cleve) Grunow in Cleve et Grunow (pseudo-raphe valve)

24. **Achnanthes brevipes** Agardh

25-27. **Achnanthes brevipes** var. **minor** Peragallo et Peragallo

28-34. **Achnanthes brevipes** Agardh

35-37. **Achnanthes** spp.

38,39. **Achnanthes brevipes** Agardh

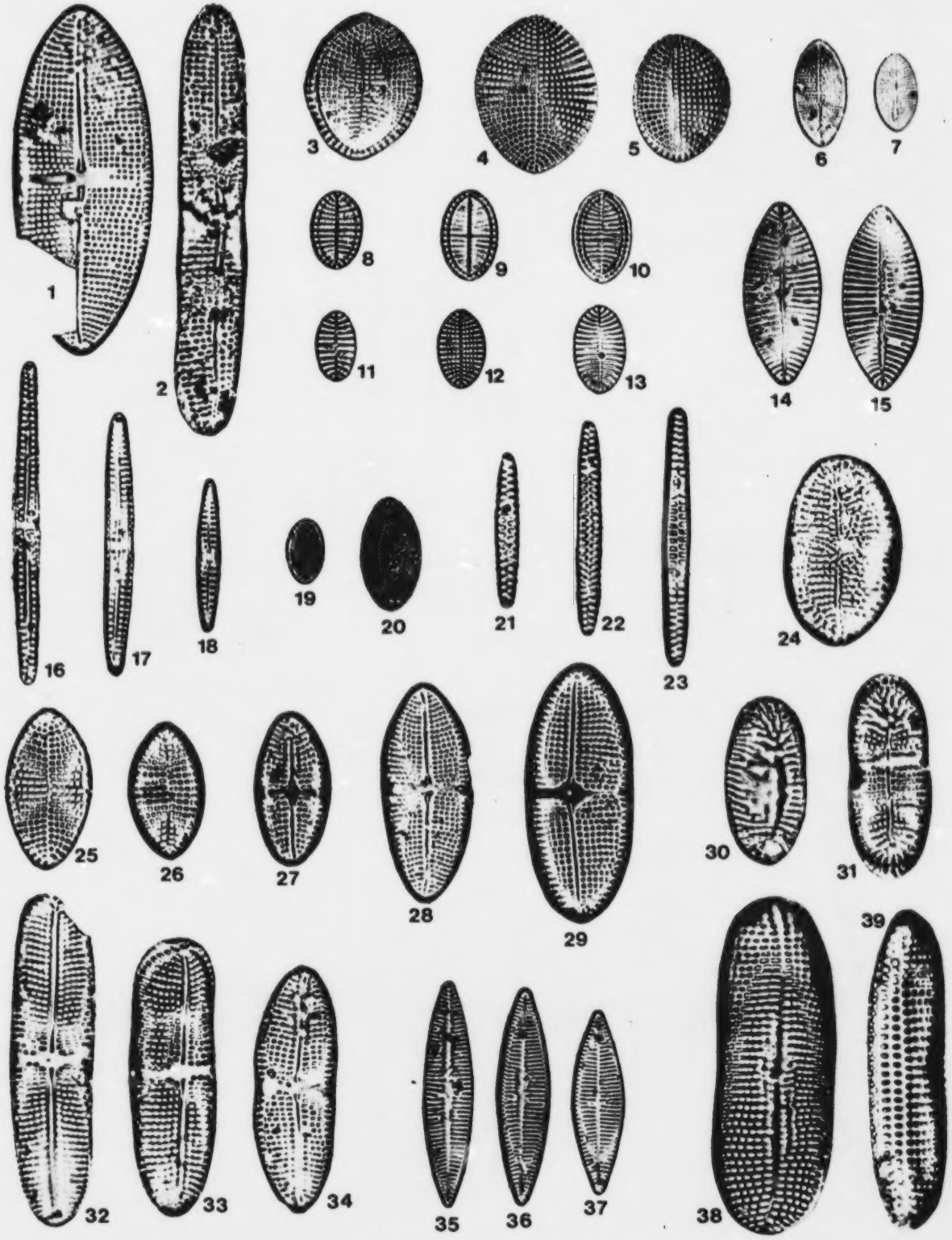
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PLATE 11

(Magnification x800)

Figure 1-2. **Grammatophora arctica** Cleve

3. **Grammatophora angulosa** Ehrenberg

4-7. **Trachyneis aspera** var. **media** (Grunow) Cleve

8. **Distephanus octonarius** (Ehrenberg) Deflandre var. **octonarius**

9. **Biddulphia aurita** (Lyngbye) Brébisson & Godey

10-11. **Rhizosolenia hebetata** fo. **semispina** (Hensen) Gran

12. **Surirella** sp.

13. **Campylodiscus angularis** Gregory

14-16. **Licmophora** spp.

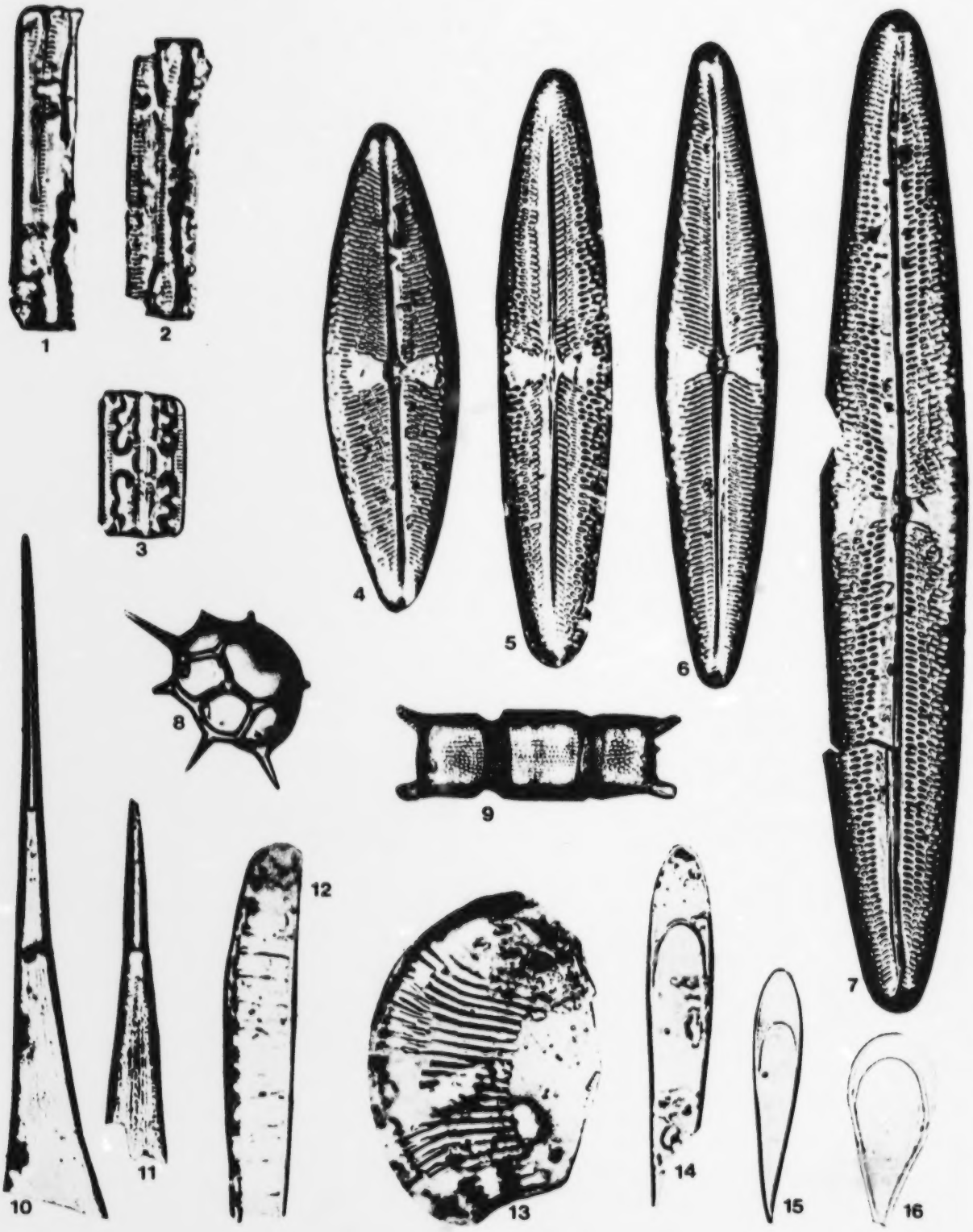
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PLATE 12

(Magnification x800)

Figure 1-2. **Synedra tabulata** (Agardh) Kützing

3. **Opephora marina** (Gregory) Petit

4. **Synedra camtschatica** Grunow

5. **Synedra camtschatica** var. **finnmarchica** Cleve et Grunow

6. **Thalassionema nitzschioides** (Grunow) Van Heurk

7-10. **Fragilaria** spp.

11-12. **Nitzschia** sp.

13. **Nitzschia marina** Grunow

14,15. **Synedra tabulata** (Agardh) Kützing

16,17. Undetermined form

18-20. **Nitzschia cylindrus** (Grunow) Hasle

21,22. **Synedra** sp.

23-25. **Synedra** spp.

26-29. **Fragilaria** spp.

30-32. **Nitzschia socialis** Gregory

33,34. Unidentified fragments

35,37. **Fragilaria striatula** Lyngbye

38. **Thalassiothrix** sp.

39,40. **Nitzschia** spp.

41. **Nitzschia sigma** (Kützing) W. Smith

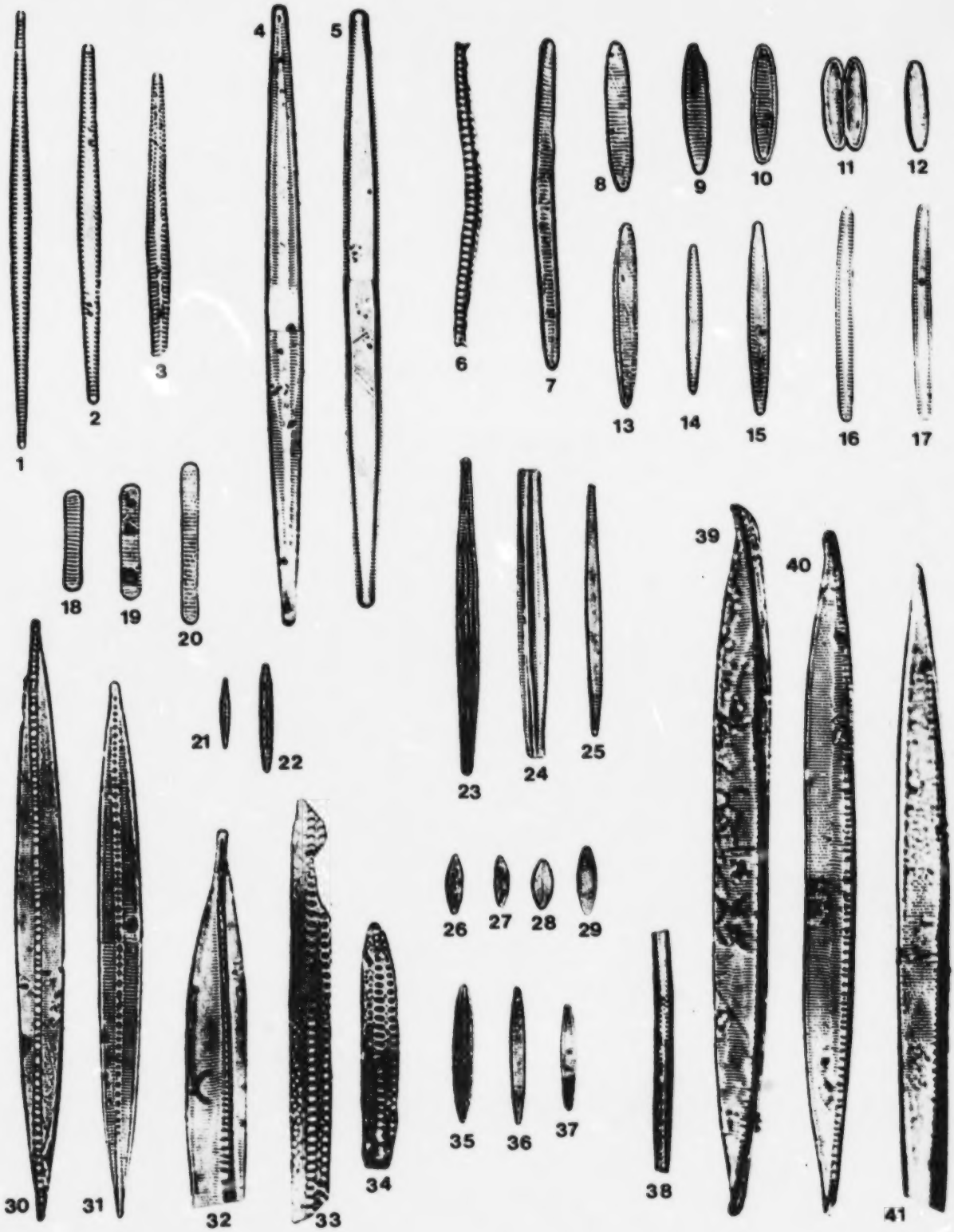
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PLATE 13

(Magnification x800)

Figure 1-3. **Nitzschia** spp.

4-6. **Nitzschia marginulata** var. **minuta** Grunow

7-12. **Nitzschia** spp.

13. **Nitzschia hybrida** Grunow

14-16. **Nitzschia angularis** W. Smith

17. **Nitzschia recta** Hantzsch ex Rabenhorst

18. **Nitzschia** sp.

19. **Nitzschia** sp.

20. **Nitzschia** sp.

21-23. **Nitzschia angularis** W. Smith

24. **Nitzschia praelonga** Cleve

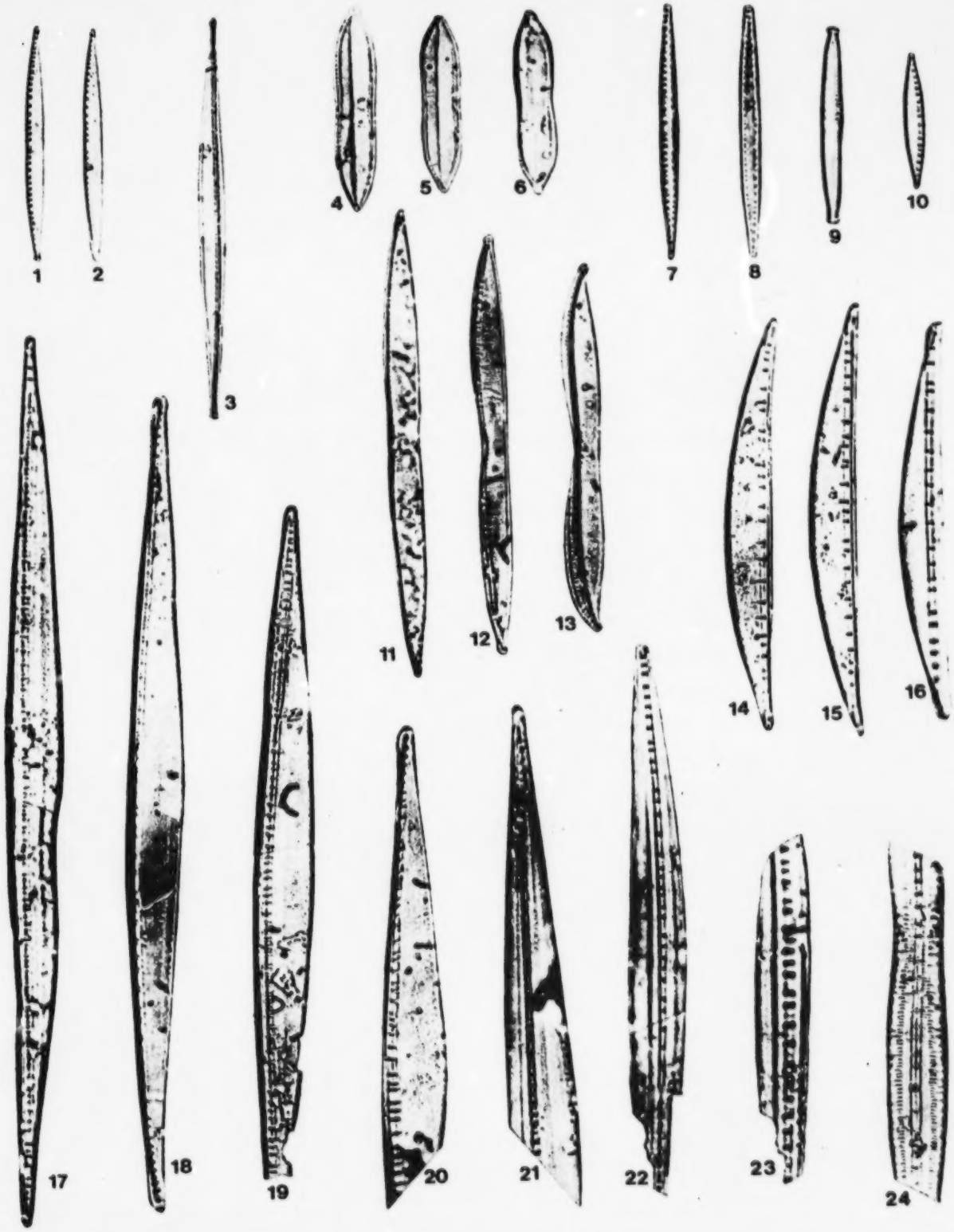
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PLATE 14

(Magnification x800)

Figure 1. **Amphora ostrearia** Brébisson ex Kützing

2-5. **Amphora lineolata** Ehrenberg

6. **Amphora laevis** var. **laevissima** (Gregory) Cleve

7. **Amphora ocellata** Donkin

8,9. **Amphora lineolata** Ehrenberg

10,11. **Amphora** spp.

12,13. **Pleurosigma longum** Cleve

14. **Pleurosigma strigosum** W. Smith

15-17. **Gyrosigma arcticum** (Cleve) Cleve

18. **Amphiprora gigantea** var. **septentrionalis** (Grunow) Cleve

19. **Tropidoneis** sp.

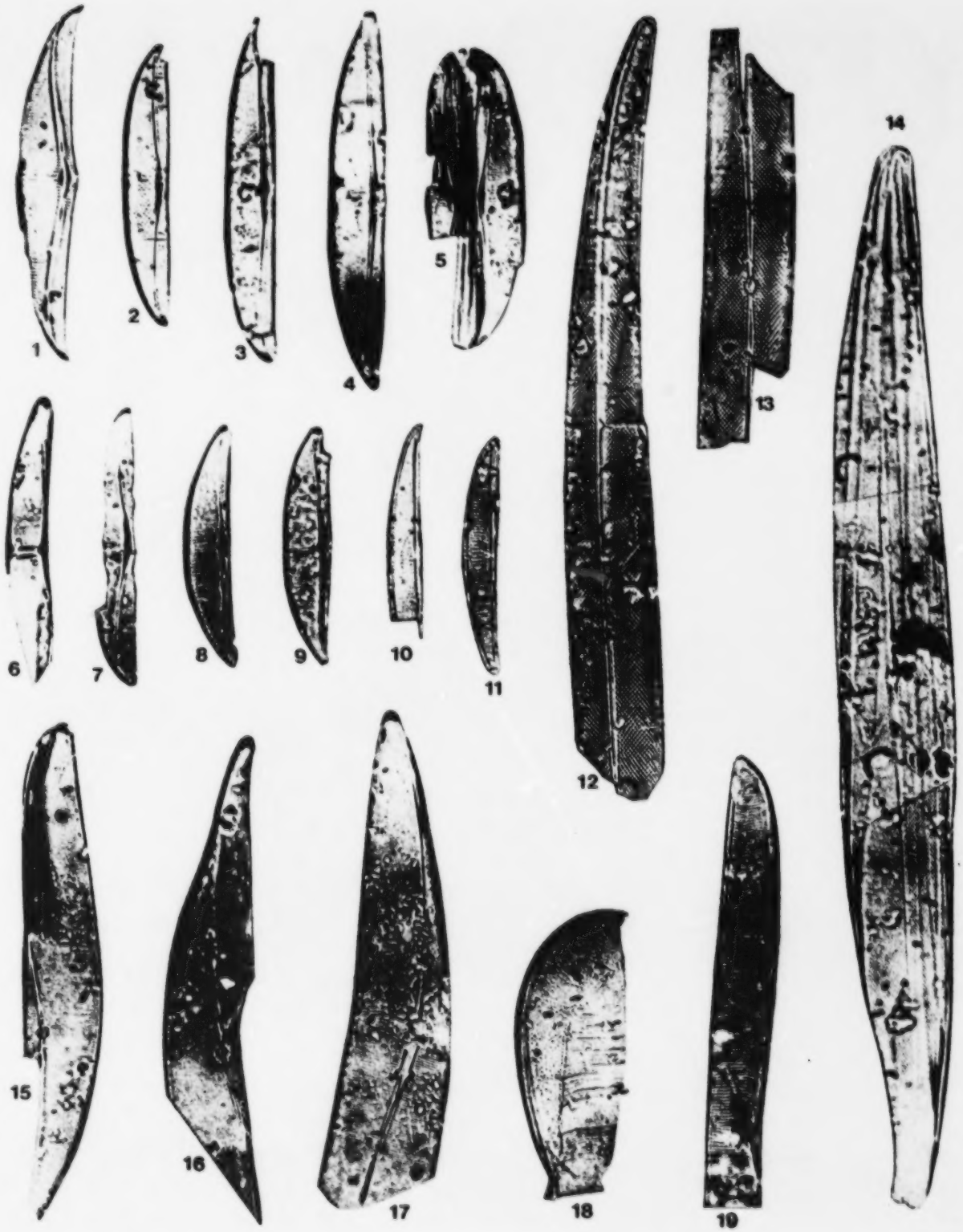
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PLATE 15

(Magnification x800)

Figure	1,2.	**Thalassiosira** sp.
	3,4.	**Achnanthes** sp.
	5,6.	**Achnanthes** sp.
	7.	**Coscinodiscus kützingii** A. Schmidt
	8-15.	**Achnanthes** spp.
	16.	**Thalassiosira** sp.
	17-19.	**Achnanthes** sp.
	20-22.	**Achnanthes** sp.
	23.	**Thalassiosira** sp.
	24,25.	**Achnanthes** sp.
	26,27.	**Thalassiosira antarctica** Comber
	28,29.	**Achnanthes** sp.
	30-33.	**Thalassiosira** sp.
	34,35.	**Achnanthes delicatula** (Kützing) Grunow in Cleve et Grunow
	36-39.	**Achnanthes** sp.

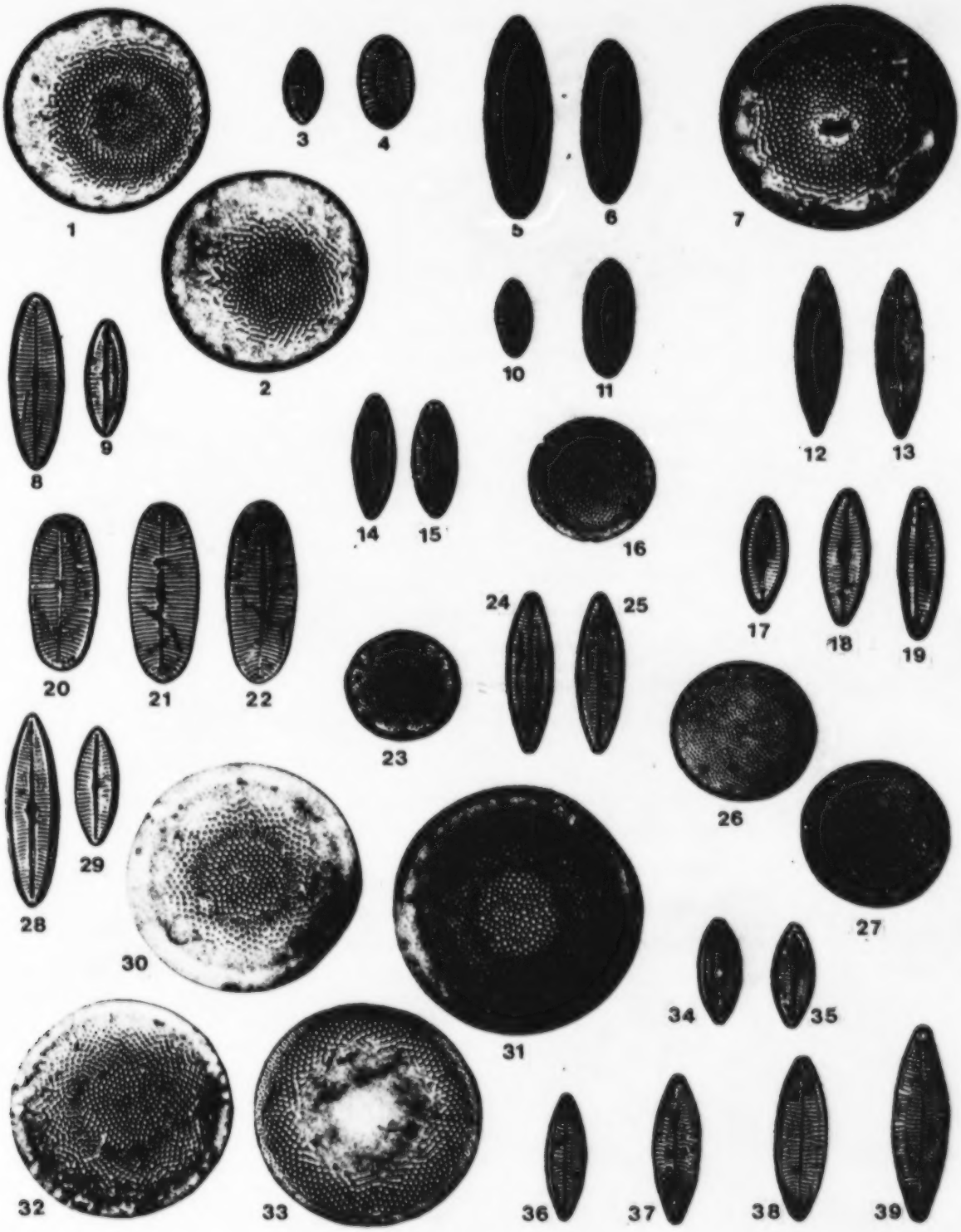
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PLATE 16

(Magnification x800)

Figure 1-3. **Thalassiosira eccentrica** (Ehrenberg) Cleve

4,5. **Bacterosira fragilis** (Gran) Gran

6. **Actinocyclus** sp.

7,8. **Actinocyclus** sp.

9. **Thalassiosira** sp.?

10. **Thalassiosira** sp.

11. **Thalassiosira antarctica** Comber

12,13. **Porosira glacialis** (Grunow) E. Jørgensen

14. **Coscinodiscus divisius** Grunow

15,16. **Coscinodiscus lacustris** var. **septentrionalis** (Grunow) Rattray

17. **Stephanodiscus astraea** (Ehrenberg) Grunow in Cleve et Grunow

18. **Coscinodiscus** sp.?

19. **Skeletonema costatum** (Greville) Cleve

20. **Thalassiosira** sp.

21,22. **Thalassiosira** sp.

23-25. **Porosira glacialis** (Grunow) E. Jørgensen

26-31. **Coscinodiscus lacustris** var. **hyperborea** (Grunow) Rattray

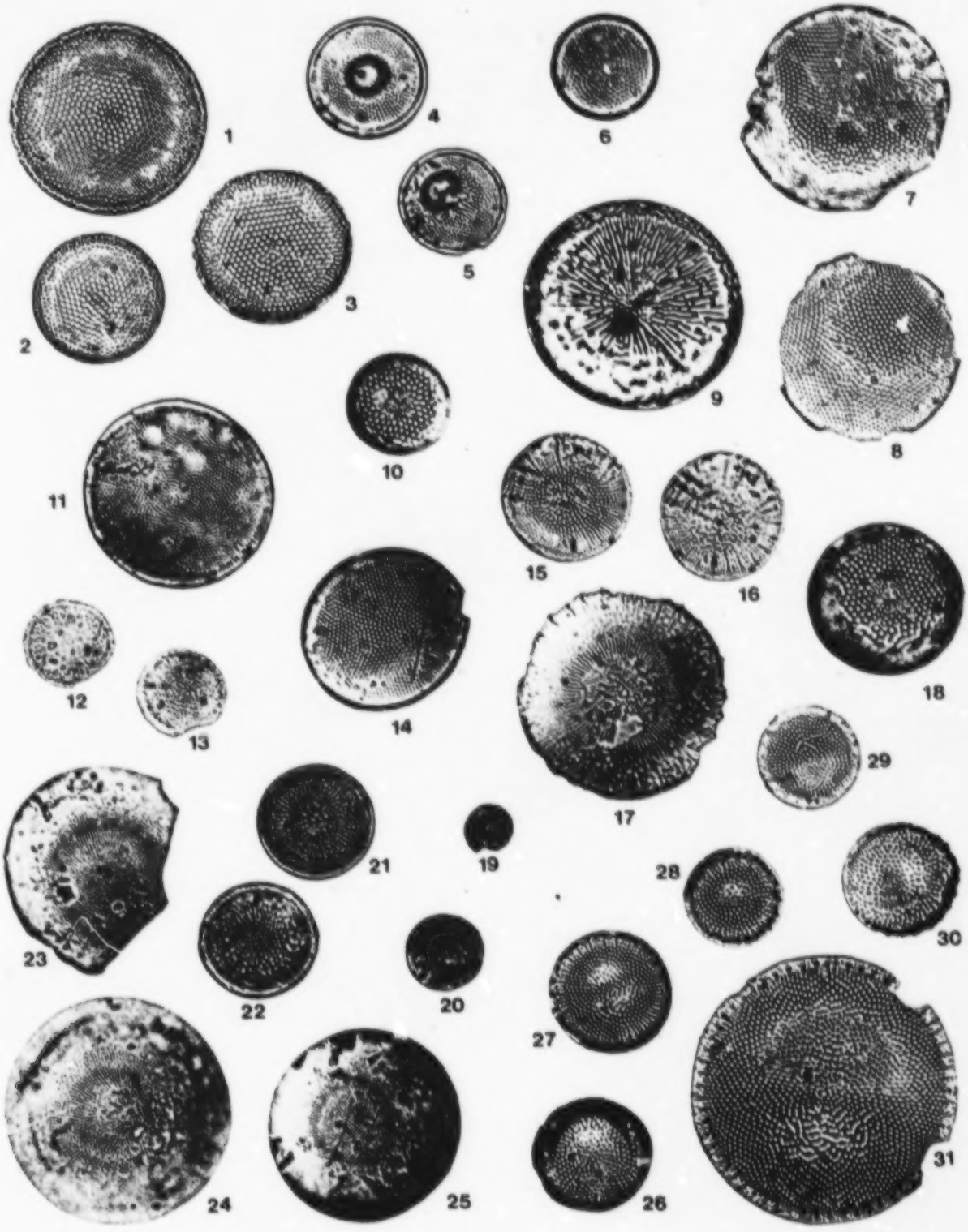
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PLATE 17

(Magnification x800)

Figure	1-4.	**Thalassiosira** sp.
	5.	**Thalassiosira** sp.
	6,7.	**Thalassiosira** sp.
	8,9.	**Thalassiosira** sp.
	10,11.	**Thalassiosira** sp.
	12.	**Thalassiosira** sp.
	13-17.	**Thalassiosira** sp.
	18-26.	**Thalassiosira** spp.
	27-33.	**Thalassiosira antarctica** Comber
	34.	**Coscinodiscus** sp.

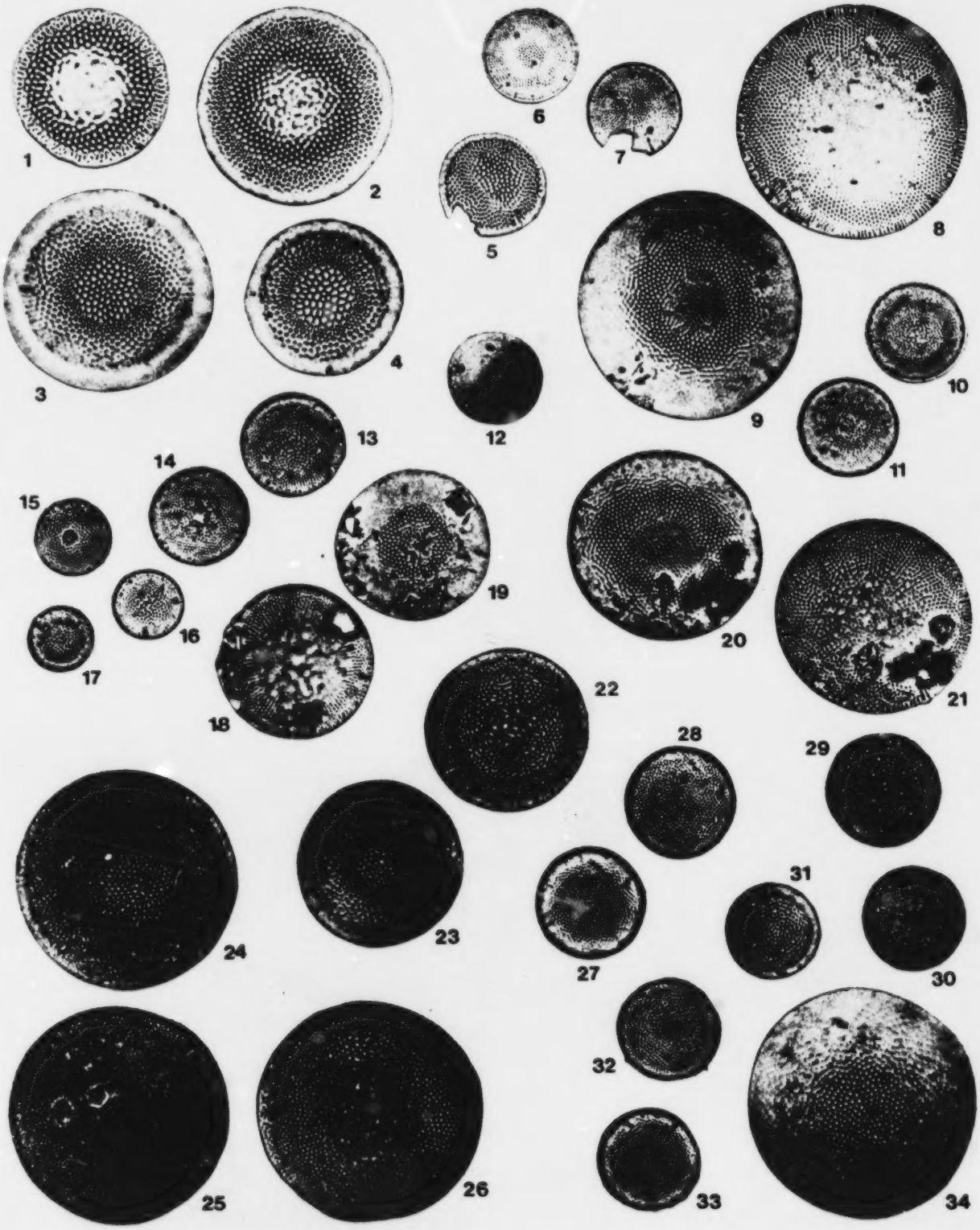
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PLATE 18

(Magnification x800)

Figure

1. **Hyalodiscus subtilis** J.W. Bailey
2. **Melosira** sp.
3. **Melosira arctica** Dickie
4. **Melosira** sp.
5. **Hyalodiscus laevis** Ehrenberg

6-8. **Podosira** sp.

9-10. **Thalassiosira antarctica** Comber

11-15. **Melosira moniliformis** (O.F. Müller) Agardh

18-20. **Podosira hormoides** var. **arctica** (Cleve ex Cleve et Grunow) Hustedt

21-23. **Thalassiosira** sp.

24. **Melosira arctica** Dickie

25,26. **Melosira** sp.

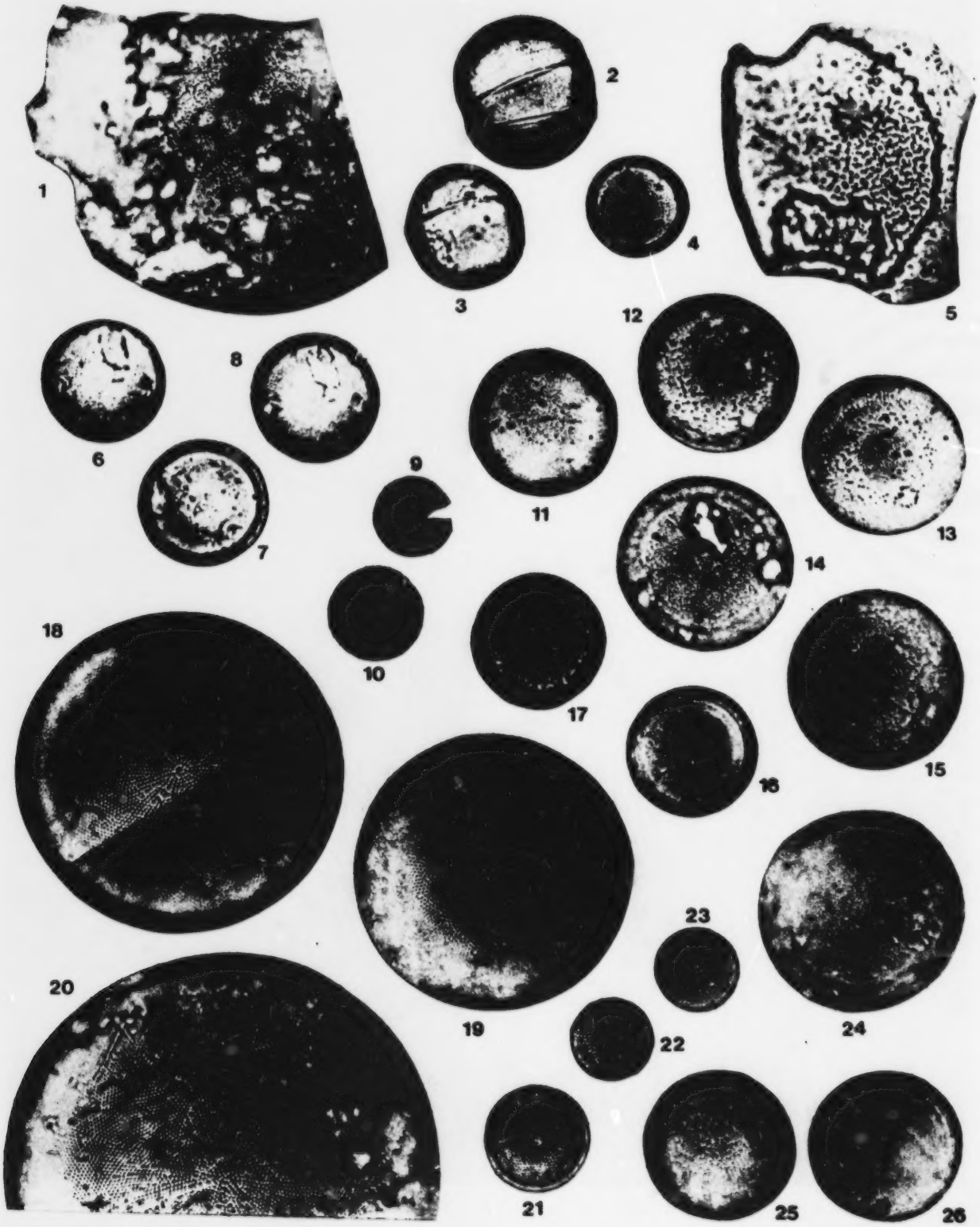
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PLATE 19

Figure 1. **Melosira moniliformis** (O.F Müller) Agardh

External view (x2000).

2. Undetermined Centric. External view (x3300).

3-5. **Thalassiosira** sp. External view (x4000).

6. **Thalassiosira** sp. Internal view (x2600).

7. **Thalassiosira hyalina** (Grunow in Cleve et Grunow) Gran. External view (x2600).

8. **Thalassiosira** sp. External view (x2400).

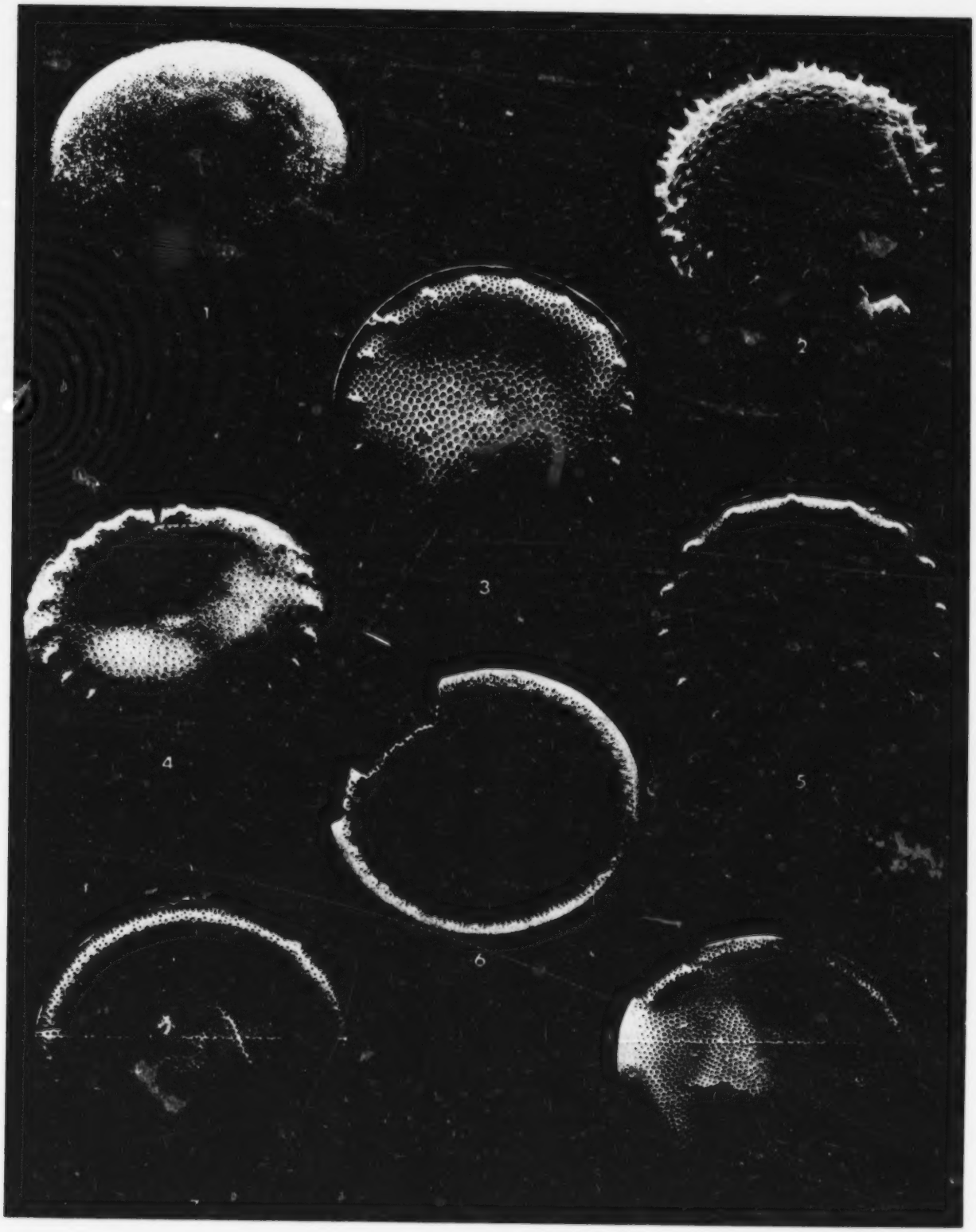
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PLATE 20

Figure 1,2. **Porosira glacialis** (Grunow) E. Jørgensen. External views. (Fig. 1 x2000; Fig. 2 x1300).

3. **Thalassiosira antarctica** Comber. External view (x2600).

4. **Thalassiosira** sp. Internal view (x3300).

5. **Thalassiosira** sp. Internal view (x2600).

6. **Detonula confervacea** (Cleve) Gran. External view (x2600).

7. **Thalassiosira hyalina** (Grunow in Cleve et Grunow) Gran. Internal view (x3300).

8. **Thalassiosira antarctica** Comber. Internal view (x2600).

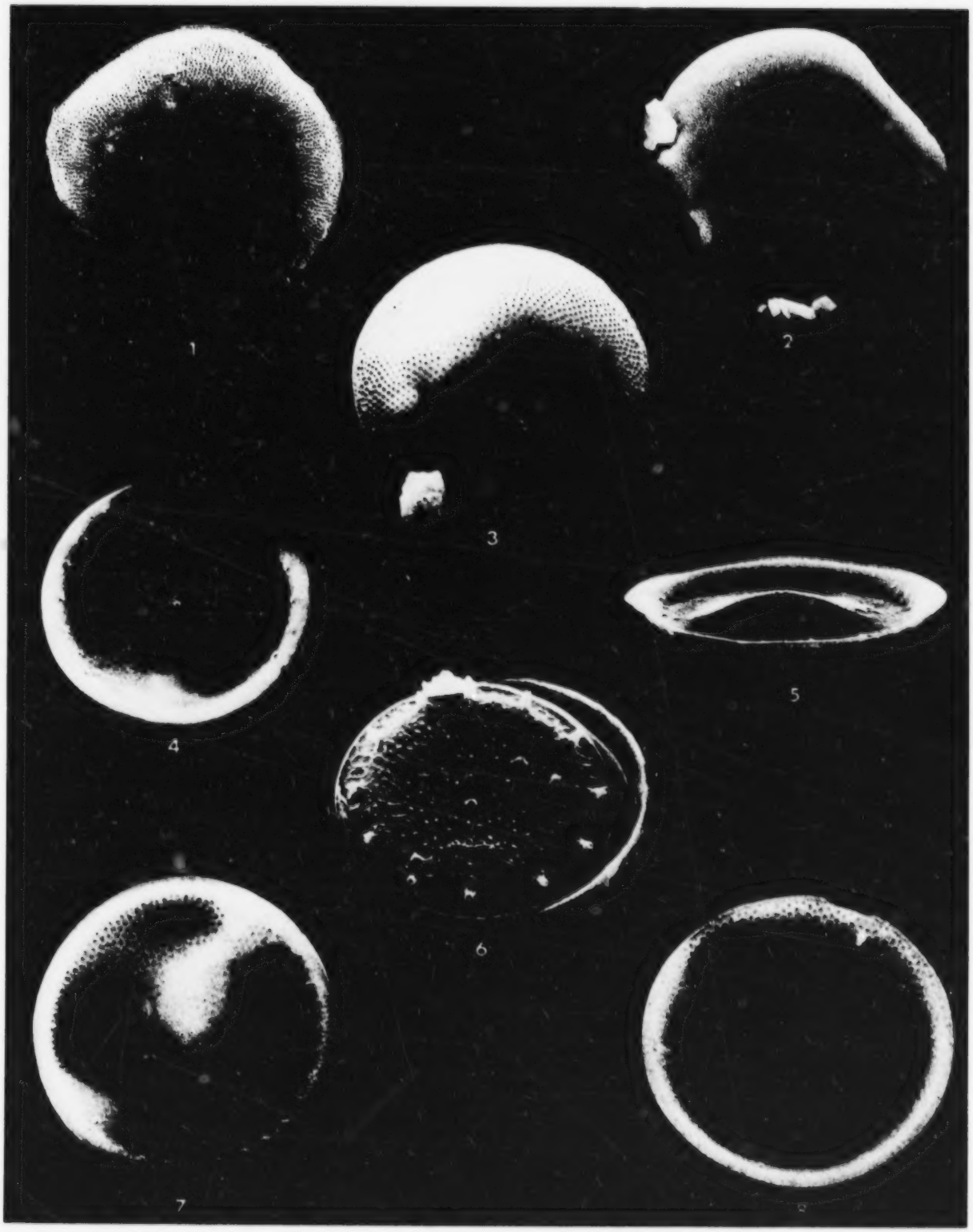
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PLATE 21

Figure 1-2. **Thalassiosira constricta** Gaarder. Internal view (x2600).

3-4. **Thalassiosira constricta** Gaarder. External view (x2600).

5. **Thalassiosira constricta** Gaarder. External view (x3300).

6. **Thalassiosira constricta** Gaarder. Internal view (x2600).

7. **Thalassiosira** sp. External view (x4600).

8,9. **Thalassiosira antarctica** Comber. Internal views. (Fig. 8 x2600; Fig. 9 x1700).

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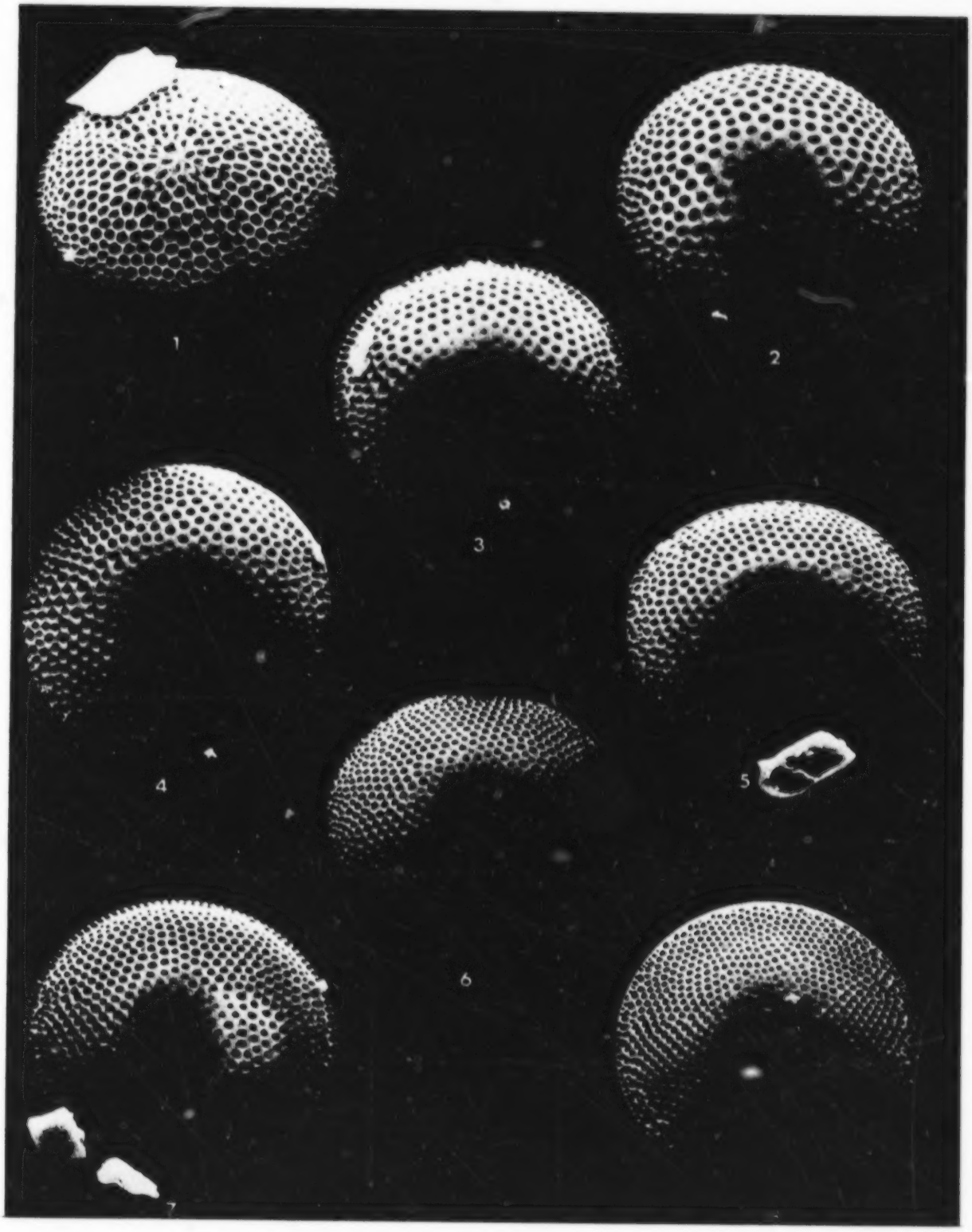
PLATE 22

Figure 1-8. **Thalassiosira antarctica** Comber. External views. (Fig. 1 x2200; Figs. 2,4 x2600; Figs. 3,5,6,7 x2000; Fig. 8 x1200).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POOR

QUALITY

ORIGINAL